THE TROPICAL PERMACULTURE GUIDEBOOK

INTERNATIONAL EDITION

A GIFT FROM TIMOR-LESTE

VOLUME THREE

REGENERATIVE AGRICULTURE

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A Gift from Timor-Leste.

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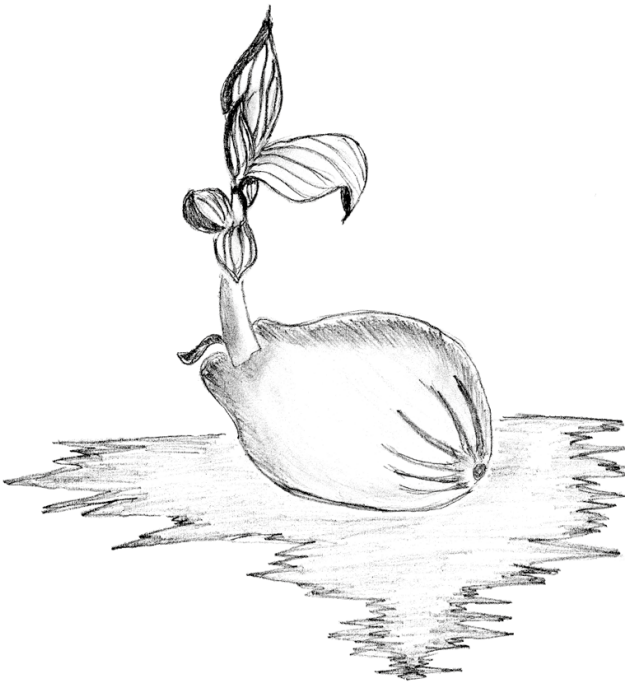
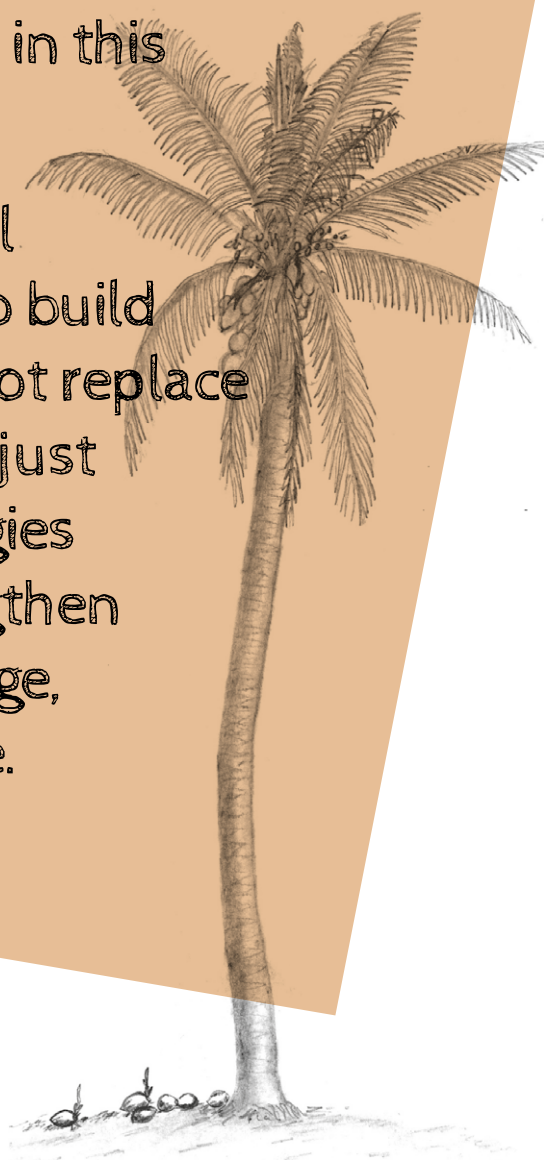


A gift from Timor-Leste to the tropical world.

This guidebook is based on an original book written specifically for Timor-Leste by Permatil. The first edition was written with help and technical assistance from many Timorese and people from other countries living and working in Timor-Leste. The wealth of knowledge and incredible illustrations by Timorese artists from the original version is incorporated and expanded upon in this new edition.

It is a guidebook for all the tropical regions of the world. We want it to build on traditional knowledge bases, not replace them. The guidebook's goal is not just to introduce permaculture strategies and techniques, but also to strengthen and augment traditional knowledge, and complement cultural practice.



Foreword

Eugenio 'Ego' Lemos
Co-Founder of PERMATIL

Permaculture, including regenerative agriculture, has been practiced by people in tropical countries for thousands of years. Today however, forest logging and unsustainable agricultural practices has had a huge negative impact in tropical countries, through the loss of the most fertile soil and biodiversity, along with the loss of indigenous seeds and knowledge. Soil destruction, such as erosion, desertification and chemical pollution, damages public health and food supply. Permaculture's approach to food and agricultural systems creates resilient and diverse food production systems which regenerates degraded soil and rebuilds soil organic matter, as well as improving the water catchment and storage, enhancing biodiversity and regenerating natural ecosystems.

Timor-Leste has much to share with other tropical countries in the world and our experiences developing regenerative agriculture as part of permaculture systems is an important example. Timor-Leste, one of the tropical countries in South East Asia, is only a small half-island nation, but rich in biodiversity and strong indigenous culture and knowledge relating to forest, seeds saving, soil and water restoration, traditional diet, herbal medicine, art and culture. A lot of the traditional farming systems, natural resources and indigenous knowledge have been diminished or lost to slash and burn and modern agricultural methods, introduced to Timor-Leste by Portuguese colonisation over 450 years and Indonesia occupation lasting 24 years after that.

After gaining its full independence as a sovereign nation in May 20th 2002, the people and government of Timor-Leste started to plan roads to recovery from the economic and environmental destruction that occurred. In November 1999, as a response to immediate livelihood and environmental concerns, a Permaculture volunteer named Steve Cran (Australian) and myself (Timorese), started introducing and developing permaculture across Timor-Leste. Initially we trained many government staff, community leaders and farmers. In 2001, with Timorese colleagues, the first national Timorese managed Permaculture organisation named PERMATIL (Permaculture Timor-Leste) was established. Since that time, PERMATIL, together with many different civil society groups, community leaders, and farmer groups have been implementing permaculture in every district and advocating for the Timorese government to implement permaculture, including regenerative agriculture, as the path way for sustainable development in Timor-Leste.

From this advocacy work, the Timor-Leste Government's Ministry of Education has now adopted permaculture into its national curriculum for primary school education as a base to implement a school garden program across the country. This is a big step forward but just the beginning.

I hope this Volume Three: Regenerative Agriculture and the Tropical Permaculture Guidebook as a whole can help other tropical counties to solve their own problems. The important part of regenerative agriculture is that it not only "does no harm" to the land but actually improves it. Traditional culture and knowledge is respected rather than being lost, integrated with new strategies and technologies that can be used by all farmers and in all climates. Regenerative agriculture builds soil capable of producing high quality, nutrient dense food while simultaneously improving, rather than degrading, the natural environment. It is a dynamic and holistic approach, incorporating permaculture and organic farming practices, including conservation tillage, cover crops, crops rotation, composting, integrated agro-forestry, mobile animal shelters, pasture cropping, integrated pest management and much more. This ultimately leads to increased and diversified food production, increased farmers' incomes, stronger local economies, and healthier, more resilient and empowered communities.

A million thanks to Bill Mollison and David Holmgren for their inspiration in bringing permaculture ideas into the world. We hope our work can continue to build on their legacy.

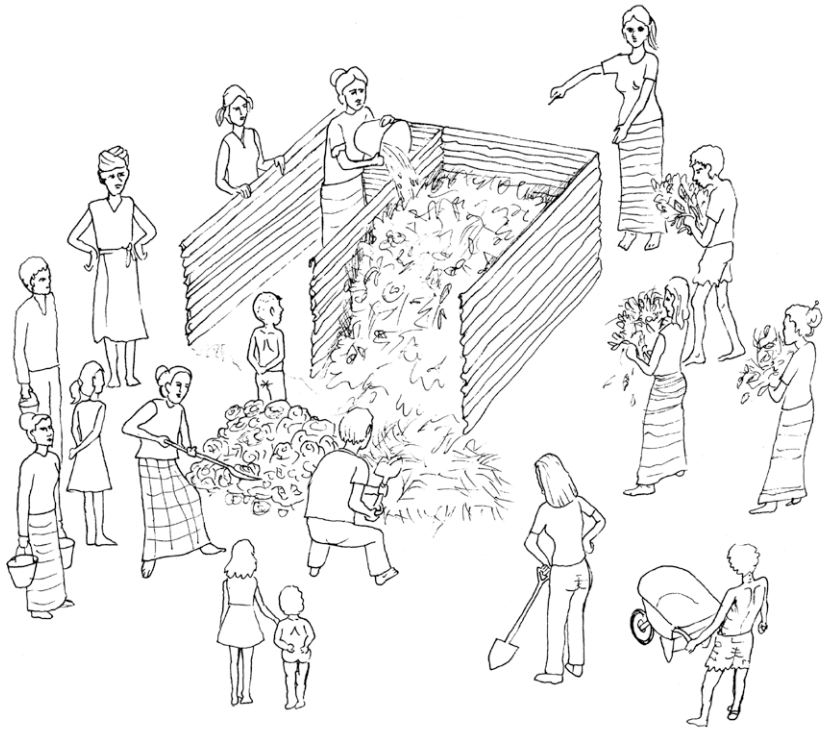
Aims of the guidebook

Our goal is to help families and communities become more resilient, sustainable and productive, not just to survive but to be able to reach their full potential and thrive.

The guidebook provides information to improve basic wealth for all people, not just material wealth, but wealth in the environment, the trees, the animals, vegetables and grains, and wealth in the people, and their knowledge, skills and connections with others. **Real wealth**!

We wrote and illustrated the guidebook for many different people to use:

- Farmers.
- Community groups and their members.
- Agriculture and university students.
- NGO and government workers.
- Permaculture trainers and practitioner.s
- Demonstration sites.
- Businesses and cooperatives.
- Schools and school students.
- Anyone wanting to become more resilient, more sustainable and regenerate their environment!



The guidebook is created to help develop new projects and for redesigning and improving existing projects, houses, farms, environments and communities.

It is written and illustrated so that people with low literacy levels can use it and people with little or no income can benefit from it.

It provides techniques and solutions at all levels — for individuals, families, communities, businesses and governments, both regional and national.

We also want the guidebook book to improve over time. So, use it, share it, learn from the results of your work, and let us know your ideas for improvements to the guidebook and we will spread your experience. As the guidebook is on the internet, we can update it every year, and your input can create a better guidebook in the future!

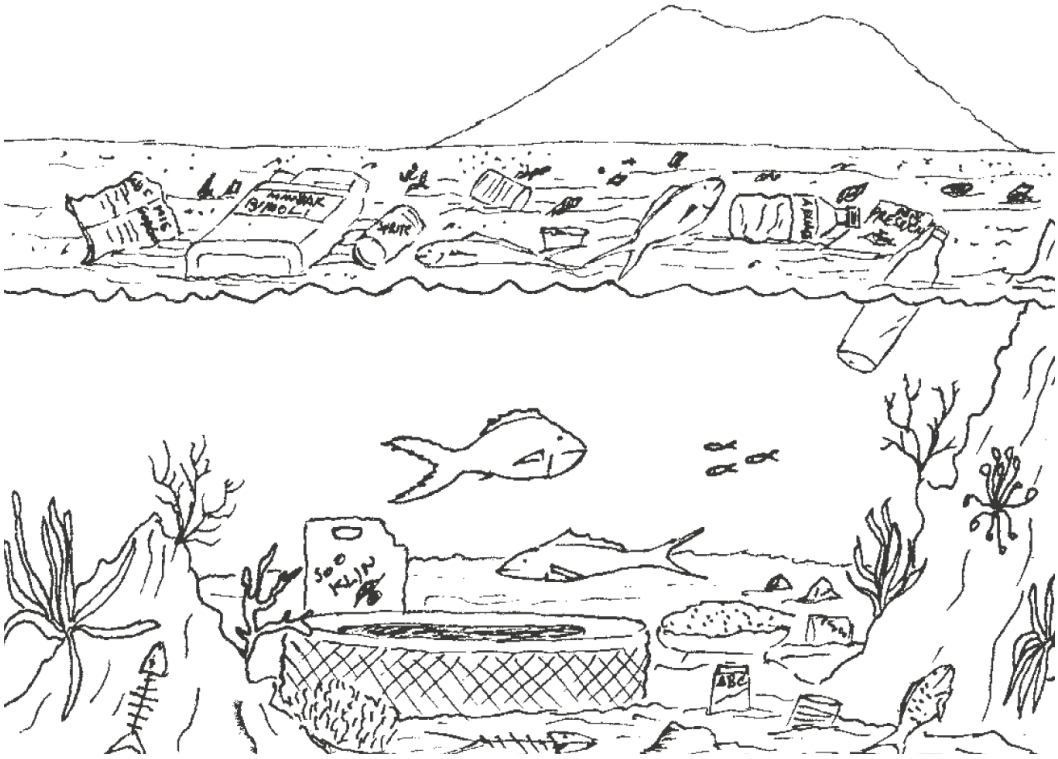
Our challenges

Globally we are facing many direct and serious challenges — to our environment, our productive land, our natural resources, and our social and community structures.

POLLUTION

Our land, water, oceans and air are in bad shape! All of them are being polluted by rubbish, chemicals, and the residues of our wasteful, destructive and careless ways of living.

Some of the problems can be repaired quickly — some will take much longer — but the solutions will have to come from big changes to how we live, how we produce and what we consume.



NATURAL RESOURCE DEPLETION

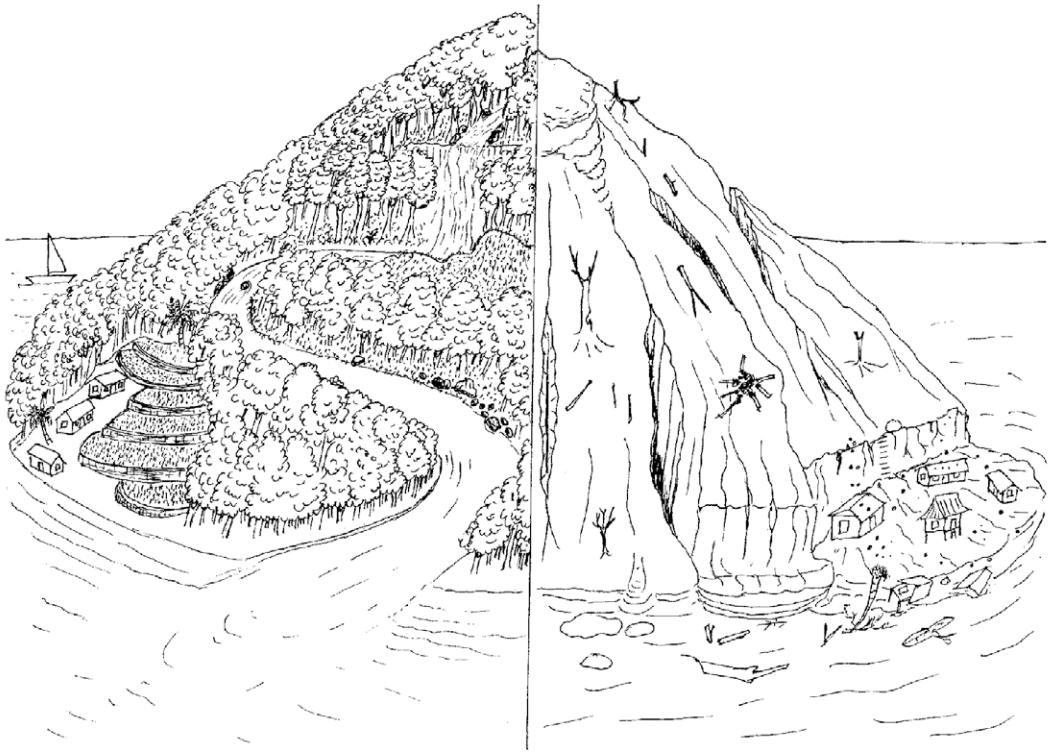
Water — underground supplies are quickly disappearing in many countries and, with bad land management and deforestation, the problem is getting worse. Rivers, lakes and oceans are more and more polluted, and rainfall is becoming more irregular as climate change takes effect.

Air — air pollution is increasing each year, causing sickness and sometimes even limiting our daily activities.

Soil — soil quality is decreasing worldwide, which increases water and resource use. Even worse is that each year there is an increase in the amount of land where the soil is so poor it cannot be used for agriculture.

Seeds — local varieties are quickly disappearing, and the range of seeds available for farmers is getting less and less. The problem leads to increased costs, higher pest problems, higher dependence and less genetic diversity.

Forests — deforestation continues and as it does, the amount of wood available to use decreases. Destruction of forests is a huge problem as not only do they affect rainfall, they are the world's lungs that turn the carbon produced through burning oil and gas into clean air. Forest depletion also negatively impacts on water supply, and causes erosion and landslides.

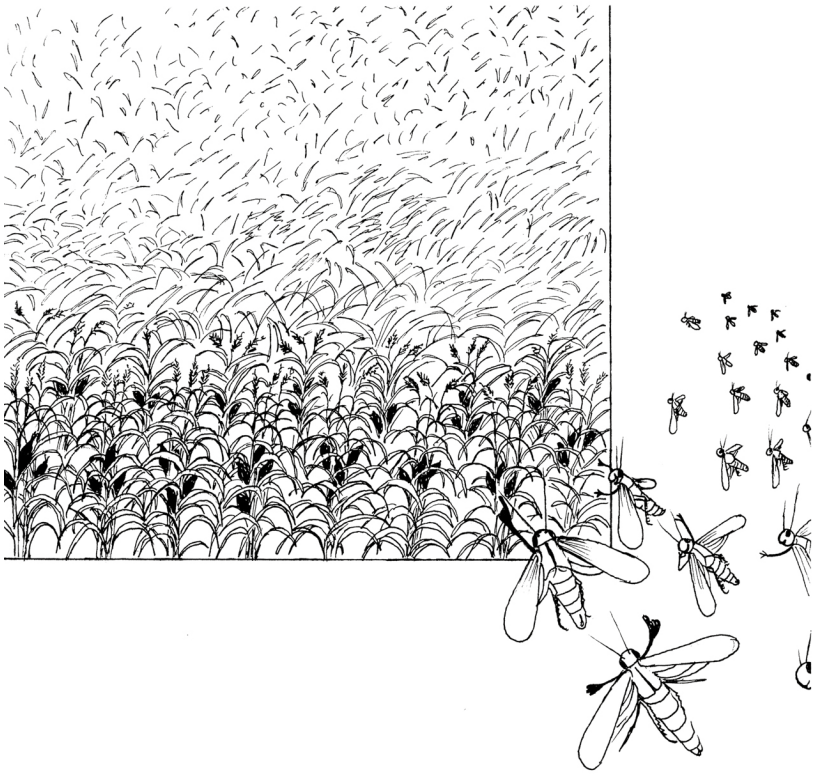


Plant, animal and insect diversity and numbers — The diversity of life on earth is decreasing rapidly creating imbalance for systems both in the natural environment and our food production. The systems become more fragile as a result and more vulnerable to climate change.

Oil, coal and natural gas — fossil fuels — these are finite resources and at the rate we are using them, we have reached the point where they are becoming more expensive, more environmentally destructive to extract and create pollution that we definitely cannot afford to create.

CLIMATE CHANGE

A lot of the technology and changes in our way of living that have helped to make life easier and better for many of us are also contributing to the huge global problem of climate change. It involves a long-term shift in world climate patterns, mainly the result of burning fossils fuels for our electricity, transport, food production, buildings and consumer goods.



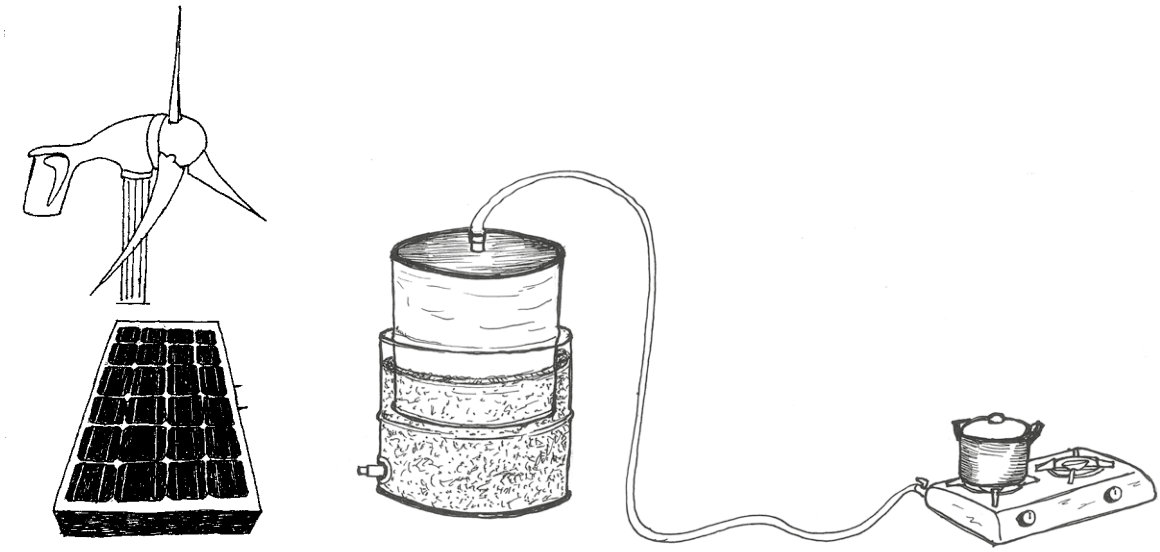
Industrial agriculture with large monoculture crops contributes to climate change

Too much carbon dioxide and methane gas — 'greenhouse' gasses — in the atmosphere is causing global warming, a rise in the earth's surface temperature. Global climate patterns are changing; rainfall is less reliable, storms are becoming more intense and temperatures more extreme. Ice and snow are slowly melting in many places as the temperature increases. The sea levels will rise a lot as the ice at the north and south poles continues to melt if we do not find solutions quickly. Low-lying areas, such as in Bangladesh, are already facing rises in sea level which have made some coastal land unlivable.

Climate change is becoming a big problem and will get much worse unless we make rapid and significant changes in how we live and how we manage the natural environment. Rather than destroy the earth's ecosystems, we must be stewards to protect it for all living things and pass on a healthy planet to our children, not controllers and consumers who leave nothing for future generations.

We are facing this global crisis because we have not understood or have ignored the consequences of our actions. Countries in the tropics have only contributed a small amount to the global problems, and yet the problems caused will affect every country. Every country must now act quickly to adopt lifestyles that will stop producing pollution, to contribute to regenerating the environment and to protect against the negative effects of climate change.

An imperative solution is to change to renewable energy sources, such as wind power, solar power, biogas, tidal and thermal energy, as quickly as possible. Changing how we produce our food and what we use and consume are also essential steps to take.



Climate change is occurring already but if we change quickly we can still minimise the impacts and consequences. If we do not act now climate change will get worse and make it very hard to live on the planet.

POPULATION

The world's population is rapidly rising, which increases pressure on resources, land for living and food production, and negatively affects the natural environment. Currently, the global population is almost 7.5 billion people!

We must:

- Find ways to reduce population growth in ways that are fair and just without imposing harsh regulations or creating hardship.
- Increase food production in a sustainable way that considers the impacts on the environment.
- Use and re-use all resources efficiently with an emphasis on quality, sustainability and recycling.
- Protect the natural environment and significantly limit our negative impacts.

URBANISATION

Urbanisation is when people move from rural to urban — cities and towns — areas. It is an enormous shift from a rural to an urban culture, especially with the changes in lifestyle that it involves. Over 50 per cent of the world's population now lives in urban areas, and this number continues to increase. Each of the world's top ten largest cities has at least 20 million people.

This creates specific pressures on the environment and natural resources that include:

- High levels of sewage and household waste.
- Much higher use of cement, steel and bitumen that increase urban temperatures.
- Bad air pollution.
- Polluted water, higher water use but less water catchment.
- High fuel use for cooking and for heating or cooling buildings.
- Houses and factories built on agricultural land.
- Resource depletion and environmental damage in the surrounding areas.

Solutions for sustainable urbanisation need to include larger-scale solutions for the challenges listed above.

GREED AND COMPETITION

The modern way of living and the values it incorporates have created many problems, such as:

- When our system values money and material wealth above all else, everything is consumed to get more money.
- Focusing on short-term material gain does not consider the long-term consequences on the environment or the planet.
- Consumerism and the consumption of goods that do not last or are quickly thrown away pollute the environment, which creates problems related to bad health, wasteful resource use and rubbish disposal.
- Many consumer goods are designed to last only a few years; they break and are replaced. The term for this is 'planned obsolescence' and it is to make more money for the businesses at the expense of the environment, causing resource depletion, pollution and climate change.
- Current financial systems still only react to problems rather than applying preventative measures so that problems do not arise at all — short-term solutions will not result in significant change.
- Big corporations and other powerful organisations/people control too many resources, are often not accountable for their actions and benefit only a few, which leads to inequality and the loss of rights and independence.

Our tools

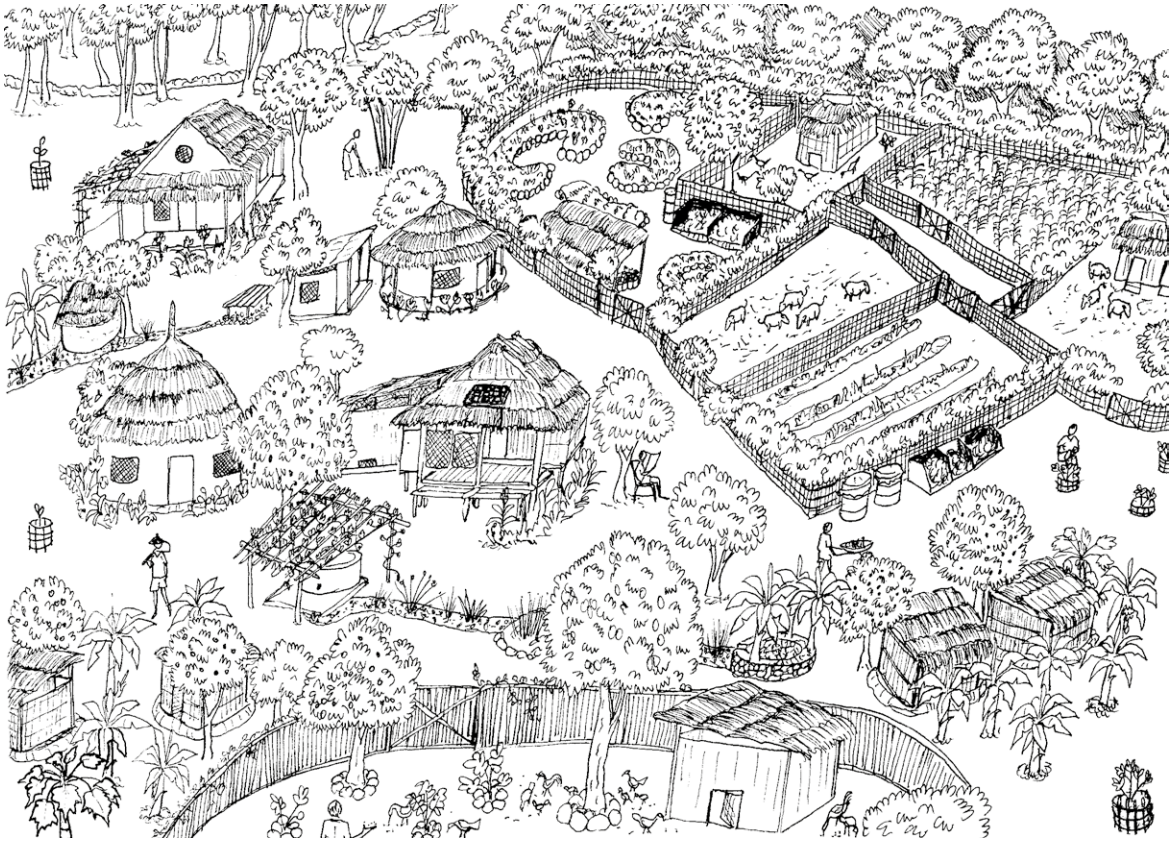
The task of overcoming these problems seems huge, but it is achievable. However, unified action must come from the majority rather than the minority, and there must be a change of mentality:

- How do we really want to live on this earth?
- How do we live well and live sustainably?
- How do we live as a part of the earth and its ecosystems, not separate as we are now?
- How do we regenerate the damaged ecosystems and the depleted soil and natural resources?
- How do we live a life that leaves the earth in a better state than when we were born?

PERMACULTURE

Permaculture involves designing integrated systems for families and communities to gain self-sufficiency and live in balance with the world around them. It is a series of strategies that provide a flexible framework for any situation, and the ability to choose and integrate the technical tools required to achieve resilience and sustainability. It facilitates the need to change our focus quickly from quantity to quality and helps to address the challenges that we face.

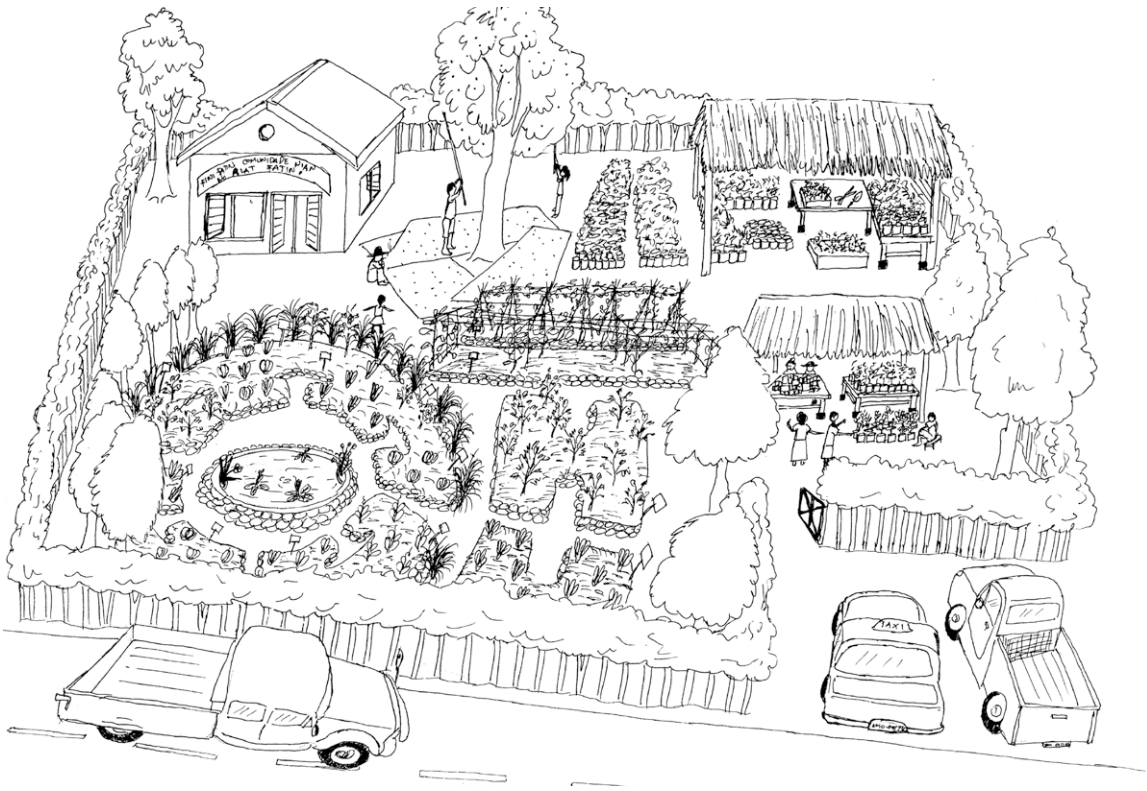
Permaculture is a regenerative process. This guidebook helps you to understand permaculture and how to apply it, especially in tropical regions. There is a lot more information available on specific topics from experts, training, books and the internet. Build on the knowledge the guidebook provides, bringing in other permaculture and sustainable living knowledge, and add your own experience too.



TRANSITION TOWNS

A concept born out of the permaculture movement, transition towns facilitate the conversion of communities from their current situation to being resilient, sustainable and regenerative. It encourages the growth from small actions to whole-town participation and provides the tools to achieve change in all facets of living — food production, transport, housing, energy and fuel, livelihoods (jobs), water, environment, economy, etc.

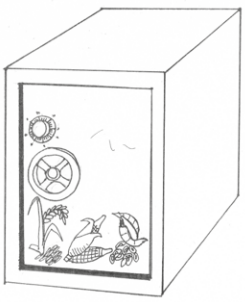
Read more in Urban and community permaculture (**Ch 4)**.



FOOD SOVEREIGNTY

70 per cent of the world's food is produced on less than five acres of land, and women produce 70 per cent of that food. This is the reality which should be encouraged, rather than following the method of large-scale monoculture crops.

Producing enough food for everyone relies on smarter, more intensive production from small landholdings using soil improving, organic, regenerative methods. Now more and more organisations, farmers, communities and governments understand that this method is the way to go. The industrial agriculture model has failed due to its reliance on outside resources, chemicals and mechanisation, the high costs and its vast scale, all of which drive people from the land, reduce livelihood opportunities, lead to soil and water degradation, and large-scale environmental destruction.



Food sovereignty embraces small-scale organic farming and food production, as well as other essential individual, social and environmental factors for producing food:

- Food is a basic human right.
- You can own the land that you farm.
- Protect the natural resources that produce the food (and ensure the people and local communities own them).
- Reorganise food trade to promote local consumption and food self-sufficiency.
- End the globalisation of hunger and reduce food wastage by protecting production, through regulation, from price speculation and corporate influence.
- Social peace — everyone has the right to be free from violence; food and food production must not be used as weapons or as means of control.
- Democratic voice — smallholder farmers must have direct input into formulating agricultural policies at all levels. Everyone has the right to honest, accurate information, and open and democratic decision-making.

Read the Urban and community permaculture chapter (**Ch 4**) for more details about food sovereignty and why it is important for all communities to achieve.

GLOBAL CHANGE

There are hundreds of thousands of organisations and millions of people all over the world working to create positive change. Their work is in many different areas:

- Environmental conservation.
- Reforestation and land protection.
- Campaigning against the pollution of air, water and land.
- Sustainable agriculture (organic, biodynamic, agro-ecological).
- Permaculture.
- Transition Towns.
- Renewable energy.
- Food sovereignty.
- Protecting native seeds, land and water.
- Indigenous empowerment and action.
- Ocean protection.
- Providing a voice for ethnic minorities, especially traditional landowners.
- Human rights and justice.
- Community resilience.
- Local food consumption .
- Animal welfare.
- Culture and art.

These organisations are community groups, cooperatives, networks, businesses, government, non-governmental organisations, large international organisations, advocacy groups, political parties and so on.

Every organisation is making a small but vital contribution to change; together there is massive change already occurring, and it is spreading. You are part of it!

EDUCATION

Learning is a key for change. This guidebook contributes in its own small way to the larger goal of education as a basic right. To address the challenges we face, we need to have knowledge of the strategies and techniques needed for broad change to occur.

How to use the guidebook

The *Tropical Permaculture Guidebook* is divided into three volumes. These volumes each have a theme to make it easier to find the information you need. Each volume contains:

- An introduction.
- A table of contents to help you find what you want to read.
- A glossary explaining technical words and terms.
- A reference section for where to find more information about the different topics.

Each volume contains six chapters that divide the information into clear, easy-to-follow sections. They are systematically organised to help you to plan, design and implement the techniques.

In each chapter there are many references to other elements and sections in the guidebook; for example, there are links to windbreaks, compost making, swales, integrated pest management, animal production and much more. This shows the connections between the different chapters and makes it easier to find the information you need.

You decide how to use the guidebook:

- Read several chapters together.
- Read them one-by-one as you need the information.
- Look up the specific strategies and techniques you want using the table of contents (TOC).

Volume One: Permaculture and People

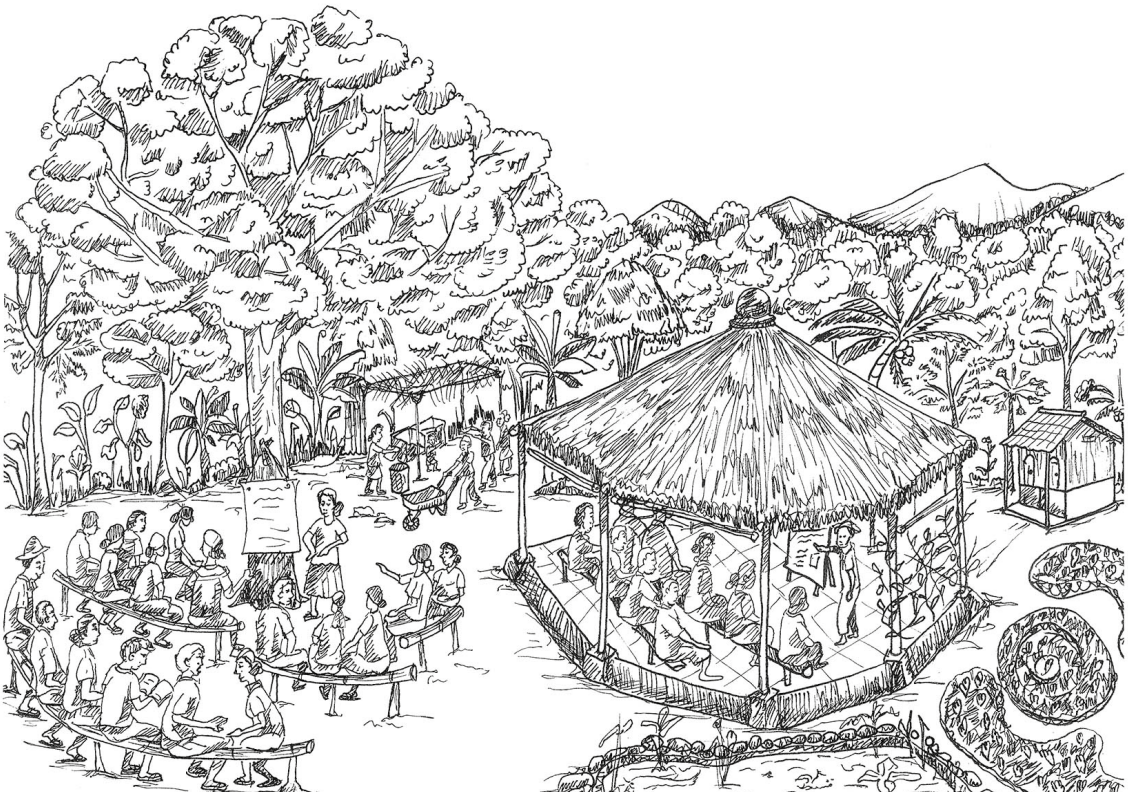
- Ch 1: Permaculture ethics and principles
- Ch 2: Natural patterns
- Ch 3 Permaculture design strategies and techniques
- Ch 4: Urban and community permaculture
- Ch 5: Cooperatives
- Ch 6: Trainers' guide

Chapters 1, 2 and 3 are the foundation for the whole guidebook, for volumes one, two and three. They provide the information to design systems and choose the appropriate techniques. They are vital to understanding how to create a complete system and the subsequent chapters in all volumes continually refer back to them. Designing and planning are part of the first step for all permaculture practice.

Water catchment methods, such as swales, micro-climates and windbreaks, as good examples of basic strategies and techniques, are included in **Ch 3 Permaculture design strategies and techniques** because they are relevant to most other chapters.

Chapters 4, 5 and 6 connect permaculture to people and communities, including practical information on:

- Local economies.
- Livelihoods, cooperatives and businesses.
- Permaculture for towns and urban areas.
- Organising and providing courses for new and experienced permaculture trainers.
- Links to related topics such as disaster risk reduction, food sovereignty and transition towns.

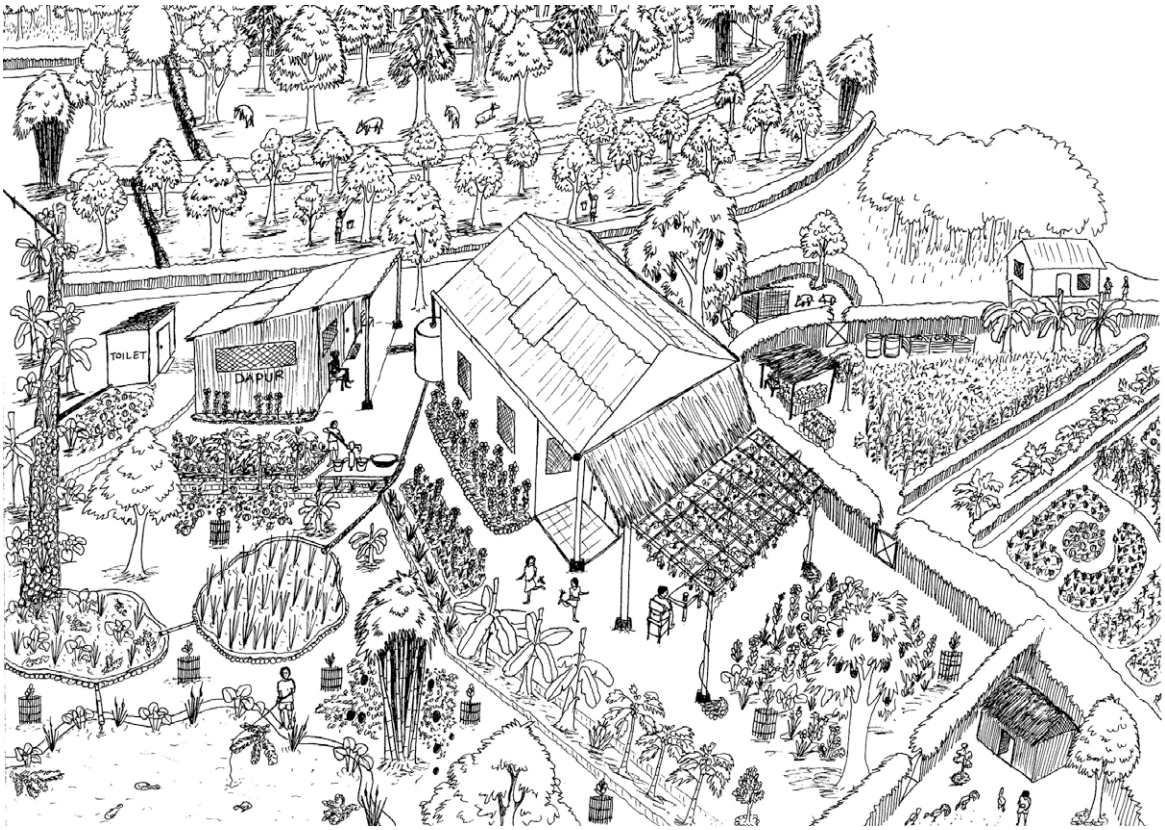


Volume Two: House and Garden

- Ch 7: Houses, water and energy
- Ch 8: Food, health and nutrition
- Ch 9: Soil
- Ch 10: Family gardens
- Ch 11: Seeds and propagation
- Ch 12: Plant nurseries

Volume two includes information that directly relates to families, family houses and family garden production. It also links these ideas to community-scale techniques because families are always part of communities and function better when they are part of a strong community. The chapters all have direct connection with each other, and can be read and used as parts of a single integrated system.

Chapters 9, 11 and 12 are foundation chapters for many chapters in Volume Three and an important starting and reference point. In Volume Three chapters, such as **Ch 14 Integrated pest management (IPM)** and **Ch 17 Animals**, are also important for referencing and linking with Volume Two.

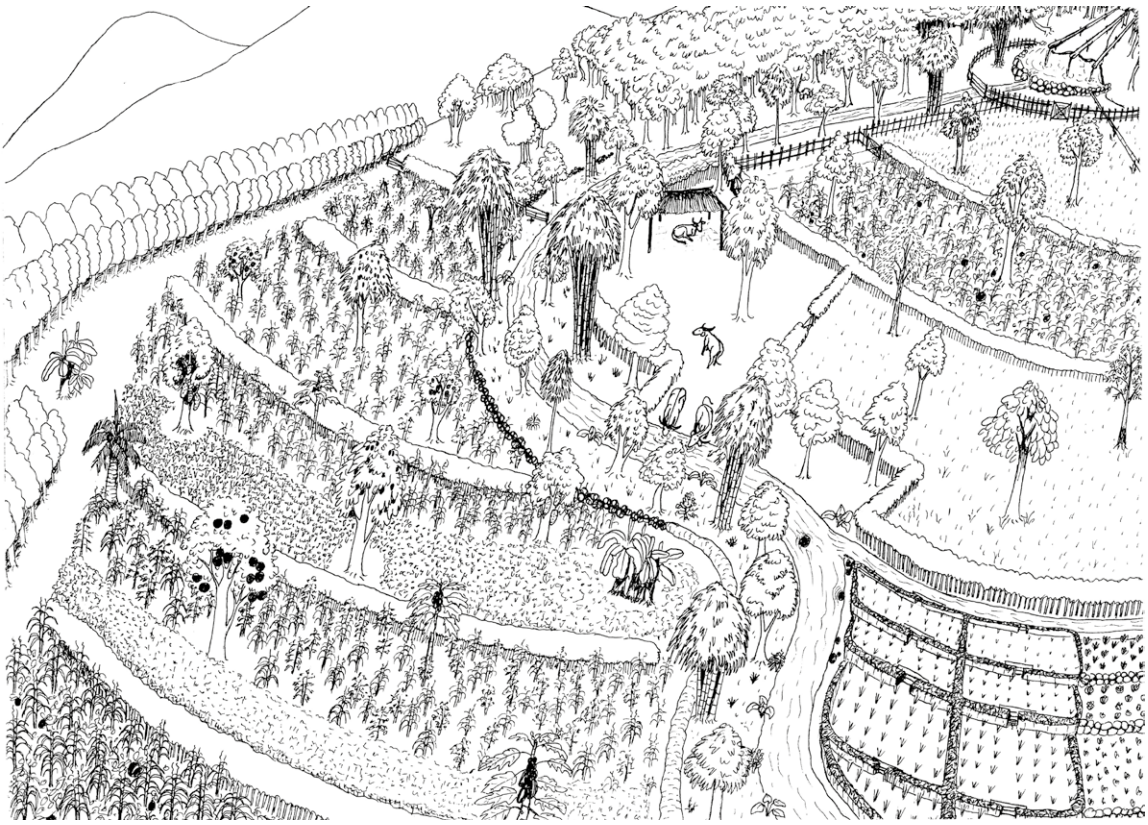


Volume Three: Regenerative Agriculture

- Ch 13: Sustainable agriculture
- Ch 14: Integrated pest management (IPM)
- Ch 15: Trees
- Ch 16: Bamboo
- Ch 17: Animals
- Ch 18: Aquaculture

This volume is called Regenerative Agriculture because the technique and strategies continuously improve the land, production and environment over time. All of the chapters in this volume refer to different parts of tropical agriculture and describe practical steps for achieving good results for families, communities and businesses. The chapters are also integrated with each other, reflected by the content and reference points within the chapters.

Volumes One and Two are important foundations for this Volume, with many chapters containing information vital for creating regenerative and productive agriculture. Volume Three also includes information in the chapters about environmental regeneration; repairing natural ecosystems and how it directly relates to healthy agricultural systems.



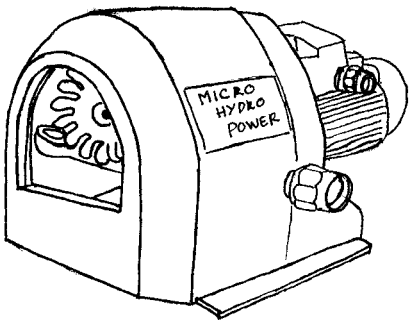
Appropriate technology

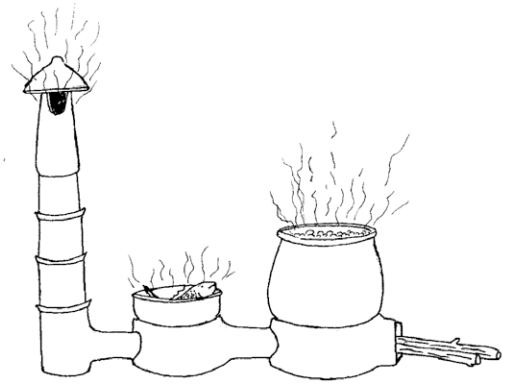
Appropriate technology:

- Is able to be understood and maintained by the people using it.
- Is affordable.
- Reduces energy use — electricity, labour, fuel, firewood, etc.
- Uses natural, renewable energy whenever possible.

Appropriate technology helps to improve the quality of life while allowing communities and countries to protect their land and the environment, and progress to a sustainable future.

In the original guidebook there was a separate chapter on appropriate technology. Instead, in this new edition these technologies as well as many new examples are included in the chapters where they fit best; there is no separate chapter. For example, renewable energy is in the Houses, Water and Energy chapter and clay stoves and solar dryers are in the Food, Health and Nutrition chapter.





We promote thoughtful and useful technological advances, not inappropriate technology that wastes resources just to make money. More and more countries in the world are moving to appropriate technology because it is smarter and more efficient. This is one of the changes we must make to reverse the current environment problems.

Think for yourself

Permaculture is about adaptation and creativity so use this book according to your needs.

If a technique mentions a material that you do not have, try to think of something else you can use to do the same job — improvise. Although the writers of the book have a lot of experience teaching and practising permaculture in tropical countries, we have not been to every household and farm in the tropics and may not know the best way to produce a solution for your situation. Follow the advice you find here and, by applying your knowledge and experience, adapt and improve it to create the best results.

One of the best techniques that permaculture can offer is how to think creatively about problems and solutions.

Use your community and join with other communities

When working with the ideas in this book remember to ask for advice from family, friends and elders in the community. The people close to you can help you plan the best design. Community cooperation and the sharing of knowledge are major elements of permaculture.

Permaculture design techniques and strategies are used in Asia, Europe, the Americas, Africa, the Pacific and Australasia – they are global! By practicing permaculture you become part of an international community. Although people adapt the techniques to suit the climate and conditions in each country, the basic permaculture concepts remain the same.

Many of these techniques and ideas are in books or are available on the internet. Use the reference section to connect you with the huge store of global knowledge. There are many good ideas and techniques being practised all over the world that you can adapt and use in your community — more are invented and used all the time.

Important ideas for implementing permaculture

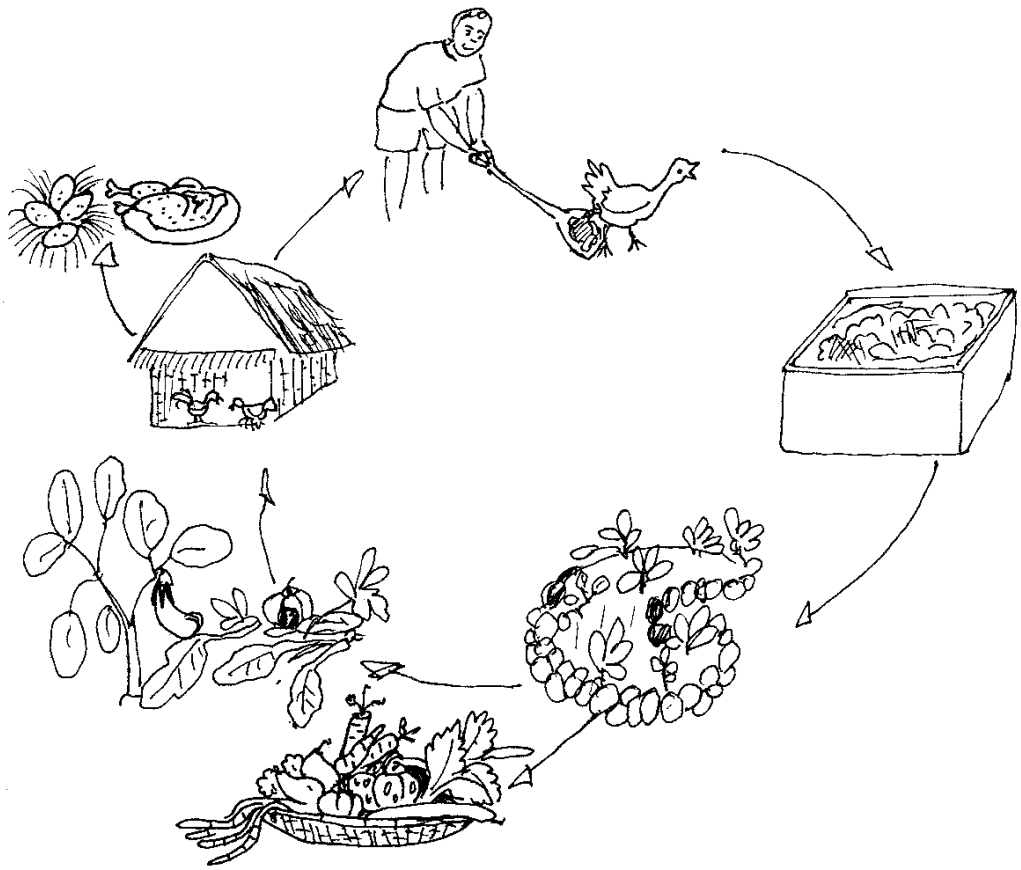
DIVERSITY

Each project, place, community or family that uses permaculture techniques is different. Each has a distinct plan using diverse techniques and various types of plants, animals and building materials. There is also diversity in climate, soil, trees and plants, water supply, knowledge and agricultural history, the shape of the land, etc., and these affect the techniques used. A technique, a plant or animal type that is appropriate in one place may not work well somewhere else, even if that place is nearby. Each situation is unique!

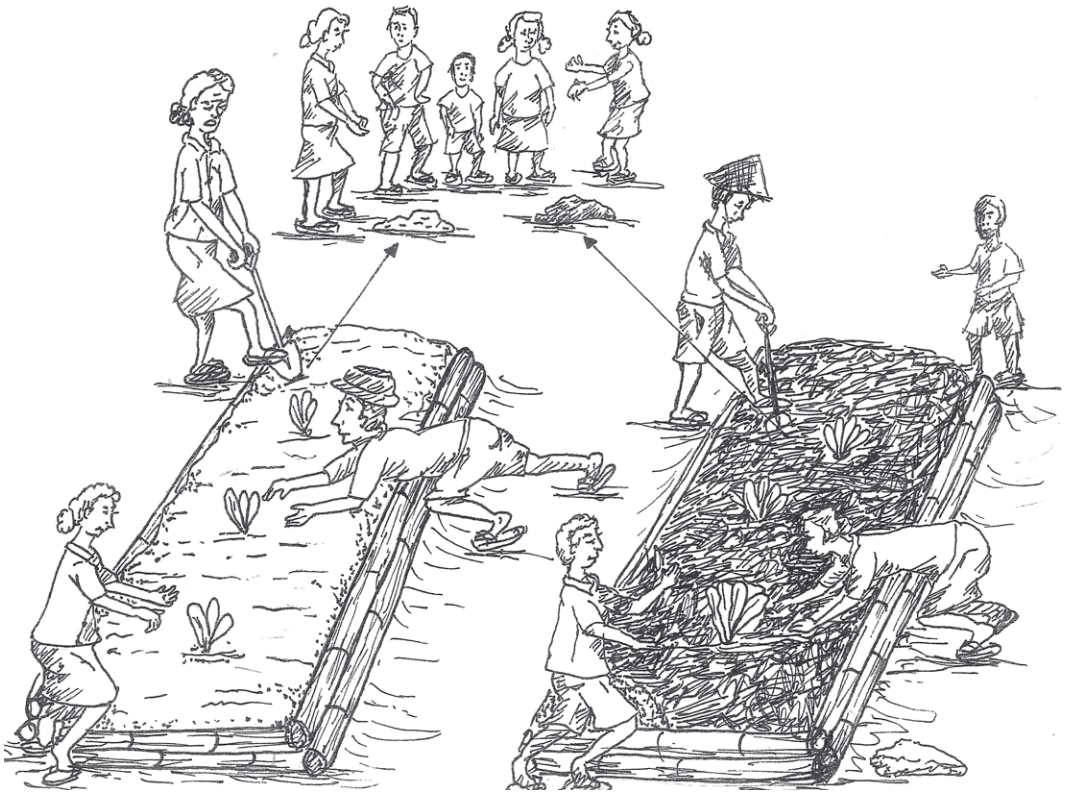
Swapping different bamboo species to increase diversity

When applying your permaculture learning, remember:

- Aim to reduce inputs (outside resources needed) and continually increase outputs (production). Always look for new livelihood opportunities.



- Always use techniques that improve not degrade the land and communities every year.
- Apply the ethics, principles and design methods to guide how to choose and use the techniques. These guides remain the same but the techniques and strategies are different each time.
- Permaculture requires that you use your imagination and adapt to the situation. Remember, conditions always change. Continual observation and adjustment are essential for dealing with different situations and problems.
- Try new techniques and experiment, but research and learn first to make sure they work on a small scale before you try large-scale application. This way you can make mistakes, trying small experiments first to learn what works and what does not. Apply your learning to improve and try again. Community demonstration plots provide a good place for trying new strategies and techniques.



No mulch / Mulch experiments

- When you use strategies and techniques that improve, restore and replenish the land for agriculture and natural ecosystems, the environment works with you and the results can accelerate year-on-year. Good long-term results can occur faster and on a larger scale than you thought possible!
- Step-by-step:
  - Try one thing, e.g. mulching, then another, e.g. animal corrals, then another, e.g. making terraces for vegetable gardens to save water. Do this as your time, money and resources allow.
  - First focus on simple ideas that are the most important for improving basic production and health; these are the first step to applying many other ideas in the future. For example, consider water supply and storage, home gardens, animal housing, compost, compost toilets, small nurseries, and clay stoves.
  - Use the ideas in the Permaculture design strategies and techniques chapter (**Ch 3**) to choose the priorities which will make everything else work better.

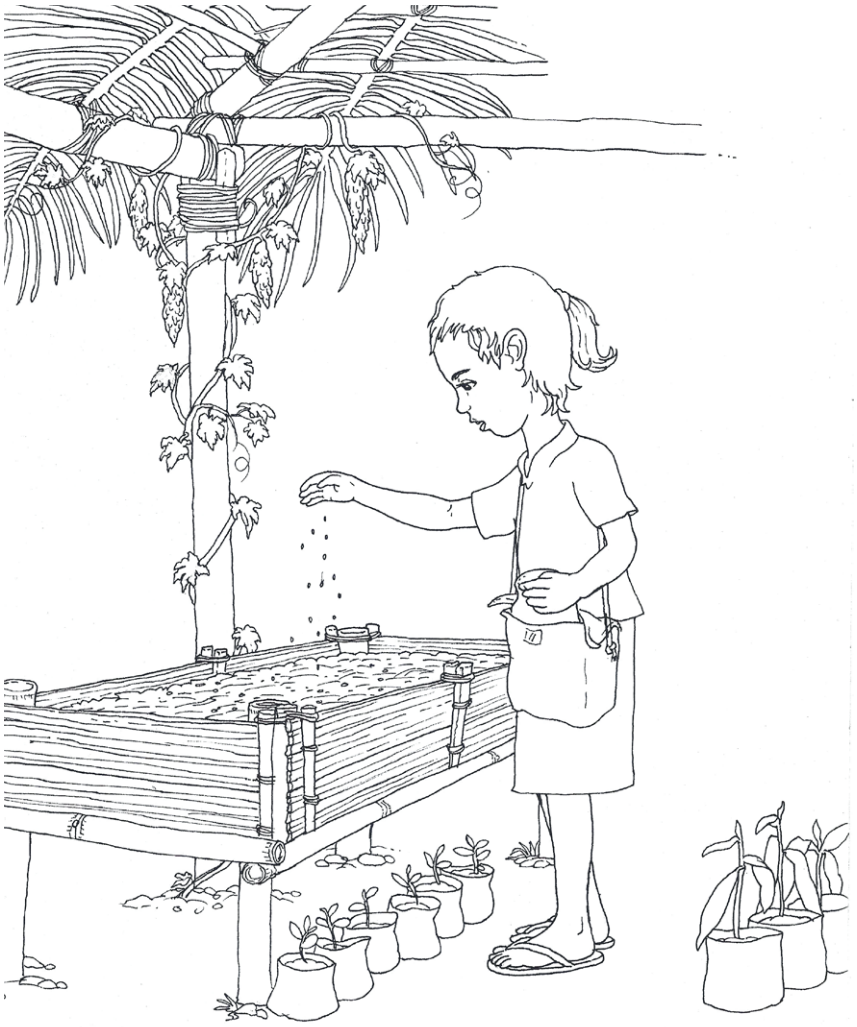
Permaculture techniques are important for reducing disaster risks, especially food shortages, erosion and landslides, flooding, drought, fires and even disease epidemics. Solutions start at the community level, while also requiring a coordinated national plan. Many techniques in this book can be used at both levels: They are easily duplicated in remote communities and integrated into short- and long-term disaster management plans.

Look towards the future. Many of the important community solutions will take time and effort to get good results: For example, improving soils, health and nutrition; building village economies and infrastructure; stopping erosion and; increasing production for fruit trees and in agro-forestry. These steps are the foundation for good health, good production and more secure incomes.

Many important environmental solutions, such as protecting forests, rivers and oceans; stopping erosion and; reducing burning, are not just about obtaining direct financial benefits. The future advantages, including gaining resilience and disaster reduction, are wide ranging and enormous. The work is necessary to protect and grow your community and your country for future generations.

The most important part of using this guidebook is to teach children and encourage their participation as they will carry the ideas into the future.

This book is dedicated to regenerating our earth and creating an abundant and sustainable future for all.



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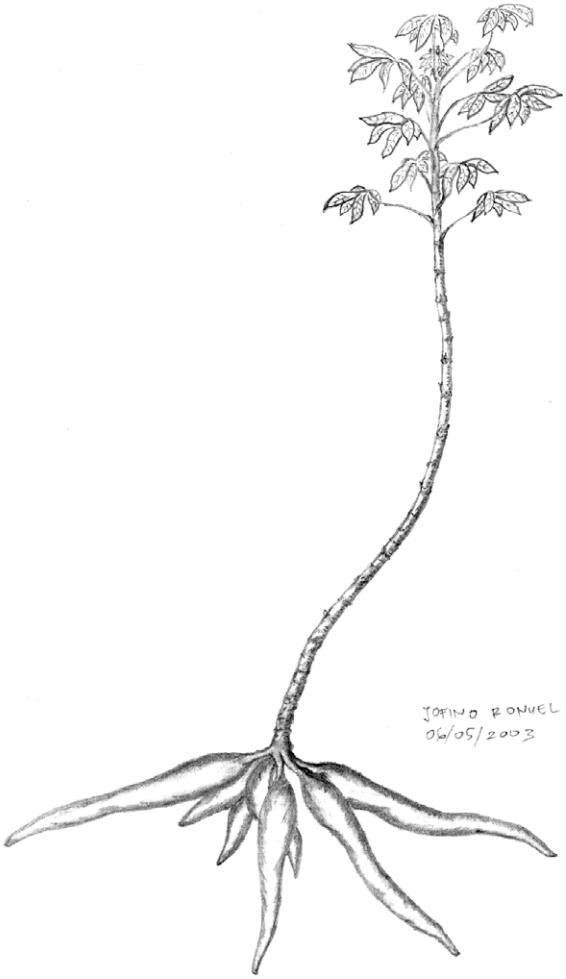
This chapter is about growing larger amounts of crops to eat, sell or trade: for example rice, corn, cassava, beans, pumpkins, potatoes, sweet potatoes, lettuces, tomatoes, and so on.

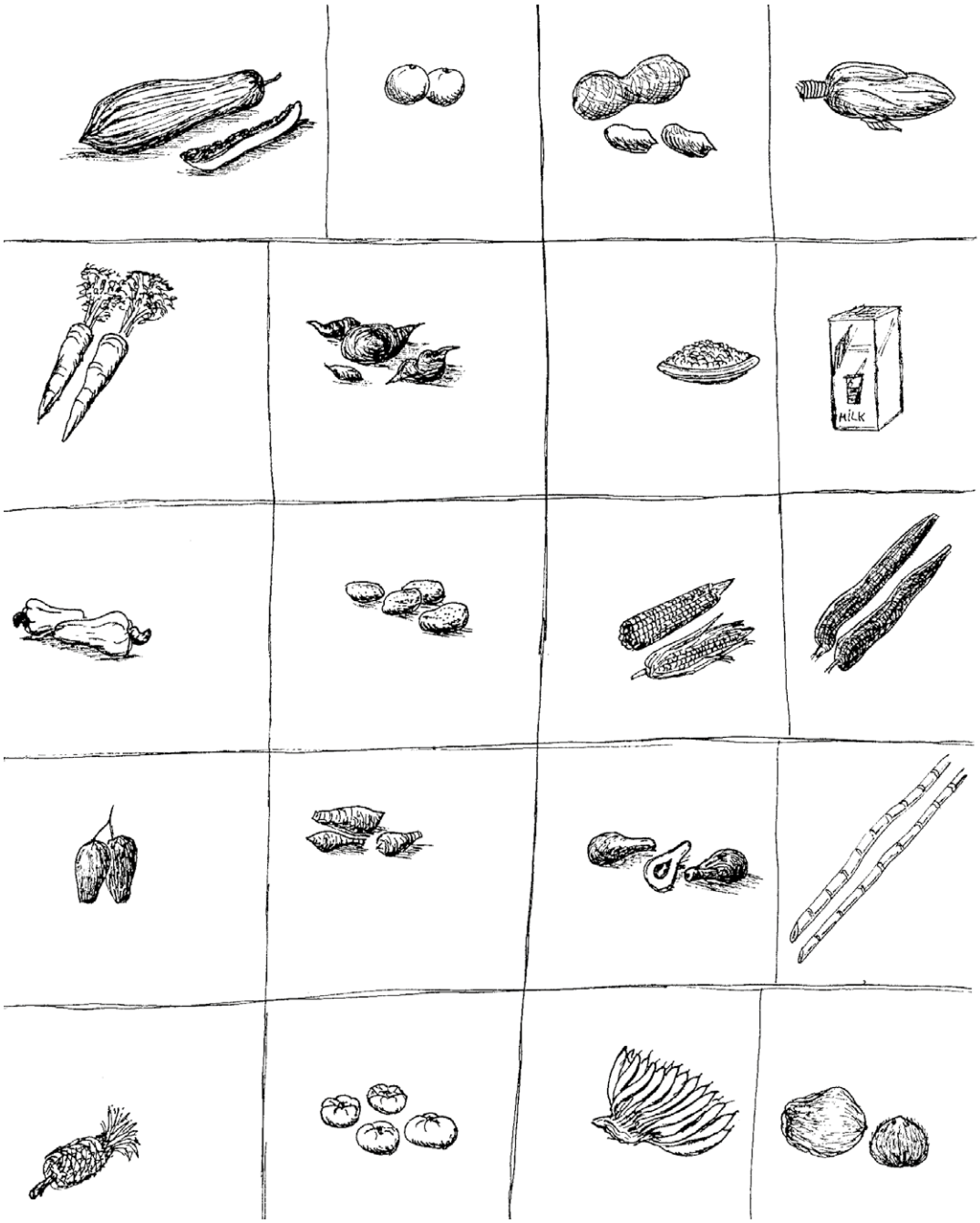
Sustainable agriculture occurs on small and large amounts of land, mountainous and flat land and, generally, in tropical countries it is based on traditional agricultural practice, and family and community-based land ownership. There are no reasons for big changes to this farming method, especially when looking at long-term sustainability, and improving food security and incomes for as many people as possible.



About sustainable agriculture

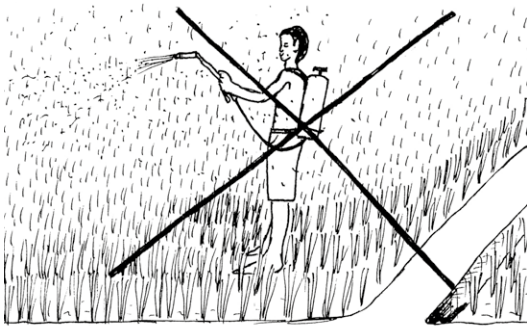
Sustainable, regenerative and resilient agricultural systems:

- Are culturally appropriate
- Improve the soil, land and conditions for production every year
- Repair damaged soil and restore natural biodiversity
- Maximise production on agricultural land already in use, in an organic and sustainable way
- Are affordable for all community members
- Form community cooperatives and farmers' groups that share resources, costs, techniques and knowledge
- Improve the storage, marketing and transport of produce
- Are diverse in yields and types of land management
- Are integrated systems



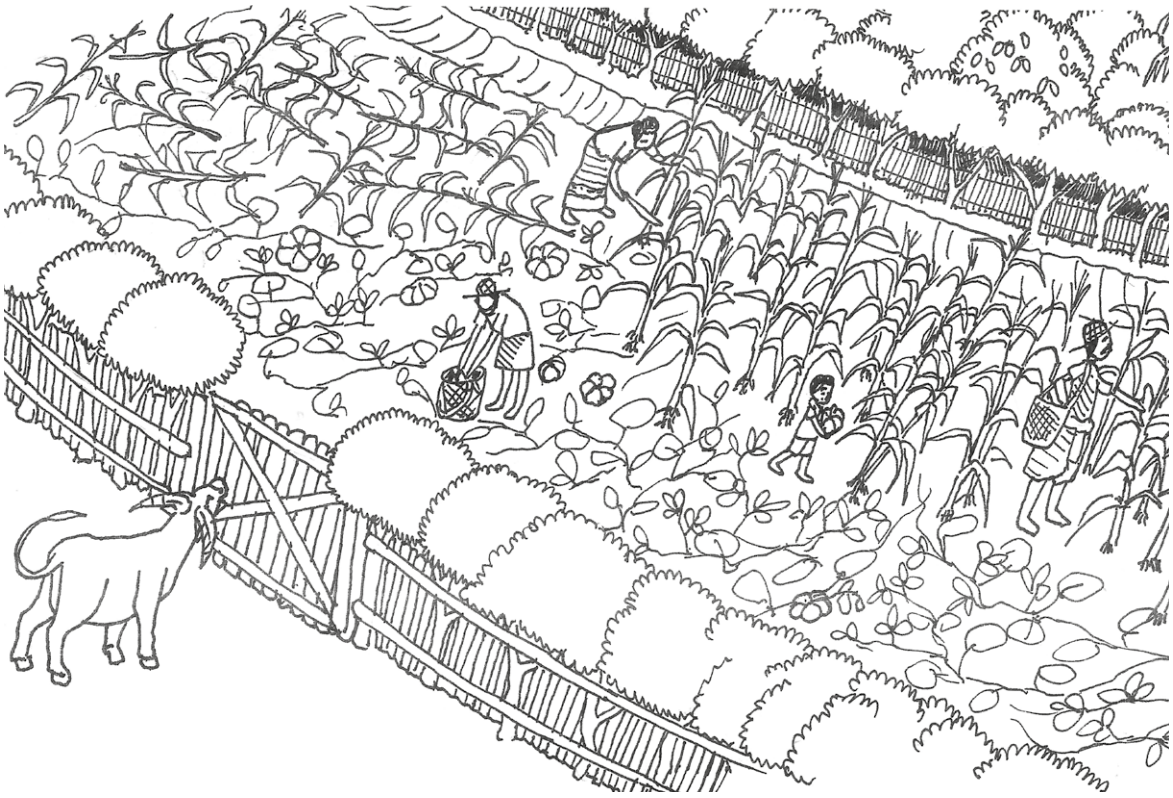
A very important component is food sovereignty, which enshrines access to and ownership of land, seeds, water and markets. Read more about food sovereignty in Urban and community permaculture (**Ch 4**).

Across the world 70% of the world's food is produced on five or fewer acres of land, and 70% of that is produced by women! This small-scale agriculture is actually the most efficient form of production.



Large-scale agriculture is only efficient with large mechanical and cost inputs, chemical fertilisers, pesticides, herbicides, fungicides and low amounts of labour. Following this farming method leads to massive urban migration owing to less need for labour, massive environmental and soil degradation, inefficient water use and the production of less healthy food.

The world's large agricultural bodies (such as the Food and Agriculture Organization [FAO]) now support and promote small-scale agriculture as the best and by far the most sustainable method for meeting the world's food needs. This includes applying organic methods using local resources as much as possible. This new direction comes together with a scientific change towards understanding that healthy living soil and a healthy environment is the essential base for food production.

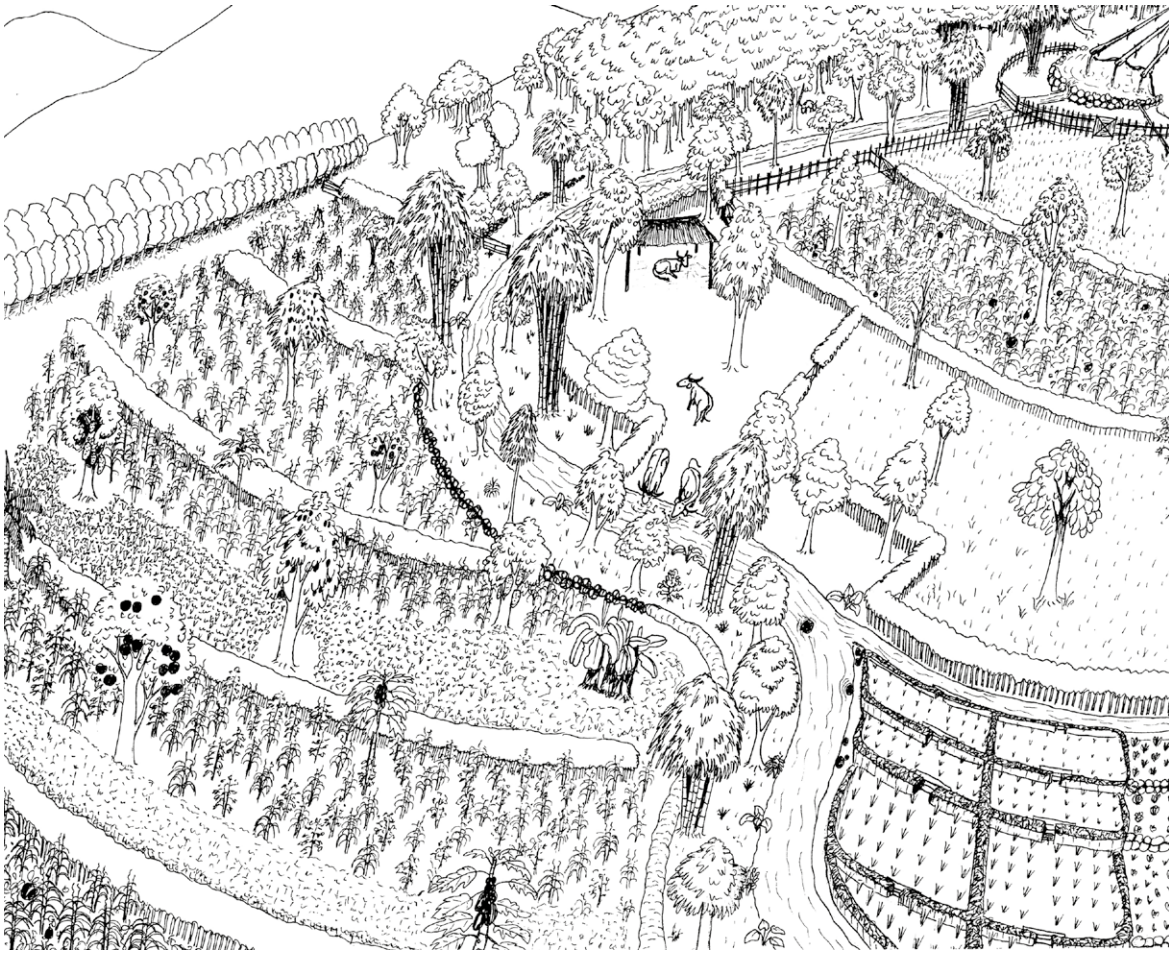


Agroecology is another good method for creating community-based, small-scale, organic agricultural systems that improve the land each year. The method is becoming more and more widely understood and used, and is very similar to permaculture.

Strengthening and improving communities and local markets should be the main focuses of any agricultural development. Export opportunities exist, as Timor-Leste's overseas coffee market shows. However, as with coffee, the best potential for exporting crops is to produce **organic** food. The demand for organic produce is constantly growing and it achieves a higher premium for farmers.

Sustainable agriculture is a very large subject, and there is a lot of traditional knowledge relating to it. Therefore, in this chapter we aim to augment this knowledge with many ideas and techniques that improve agriculture and help it move towards becoming more organic, resilient, regenerative and sustainable. The focus is on market gardens, agricultural land that is separate from the house, community agricultural land, and all grain and vegetable crops. These can be large or small areas of land, which is flat or sloping. Integration techniques with tree crops and animals are explained in this and other chapters. One specific technique, the System of Rice Intensification (SRI), is explained because it is a new technique with excellent results, using simple, cheap methods which greatly increase rice production.

Overall, systems that continuously improve, using locally and naturally produced resources, are the best. This is usually achieved with small-scale intensive systems owned by families, cooperatives or local businesses.



Sustainable agriculture system including legume tree terraces, mixed crops, paddies, animal integration, spring protection, river protection, windbreaks and natural forest on mountain tops

Agriculture and the natural environment

Agriculture is strongly connected to the land and the surrounding environment. Agriculture, wherever it is practised, affects and is affected by the land, the environment and the people.

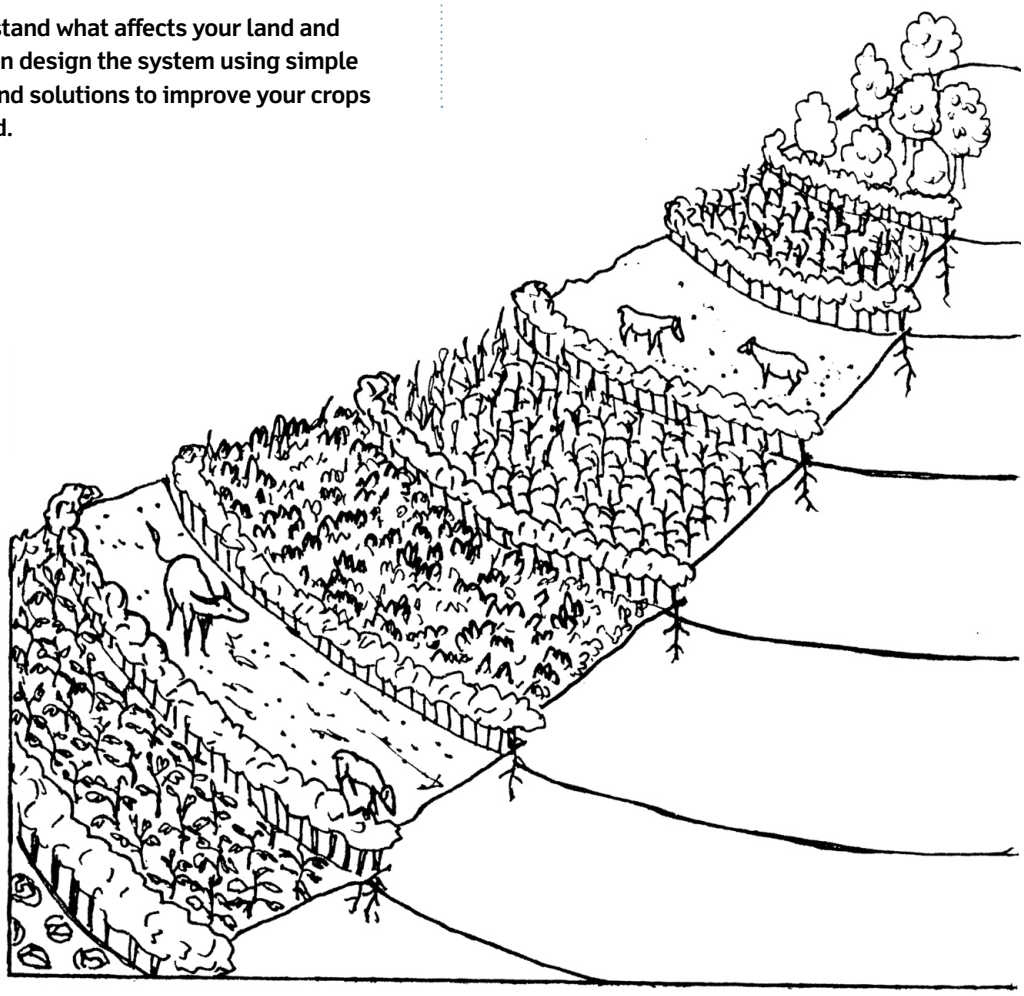
Agriculture is affected by:

- Climate – sun, rain, wind
- Surrounding land and its use
- Surrounding vegetation, animal and bird life
- Water supply and quality
- Soil type and quality
- Erosion and landslides
- Closeness to houses or towns
- Transport and marketing of produce
- Resources available to farmers and communities: e.g. seeds, tools, fertilisers, harvesting and storage equipment, and so on

If you understand what affects your land and crops, you can design the system using simple techniques and solutions to improve your crops and your land.

The agricultural techniques you use affect the land, environment and people around it:

- Use terracing and swales to protect and improve soil, and stop burning to help prevent the erosion of productive top soil and even landslides.
- Pesticides, herbicides and chemical fertilisers all pollute nearby rivers, fishponds and wells.
- Water pollution then damages the health of people, animals and birds.
- Soil quality is degraded by burning and by using pesticides, herbicides and chemical fertilisers. This also leads to the erosion of top soil.



Good steep slope land management

Protecting the surrounding environment

If you understand how your crops and land management affect your surrounding environment, you can maintain and even improve the health of people and the environment.

A healthy environment also improves agricultural production. Cleaner rivers and other water sources lead to less irrigation maintenance. More birds, small animals and insects lead to better pollination and fewer pest problems for crops. Reforestation and good land management above agricultural areas reduce flooding and landslide problems.

Problems occur as a result of bad agricultural techniques, even if they are not obvious at first. It is the same for agriculture all over the world: if you ignore the problems now, they will only become worse in the future.

Some examples:

- Weeds spread easily from agricultural land to rivers and river edges.
- Unhealthy 'dead' soil, caused by too much chemical use, needs a lot more water for crops than healthy living soil. This has a negative impact on rivers: a huge amount of water is used for agriculture and underground water tables drop quickly.
- Erosion from burning and poor soil management negatively impacts on rivers and the ocean.

Protecting natural spring
and building irrigation pipes

Any areas around your croplands that are already eroded need to be replanted. Grasses, bamboos and fast growing legume trees are best to plant in and around eroded areas.

With sustainable agricultural techniques you can prevent negative impacts on the environment, as well as improve the soil and growing conditions year on year for you and for future generations.

BEWARE OF CHEMICALS!

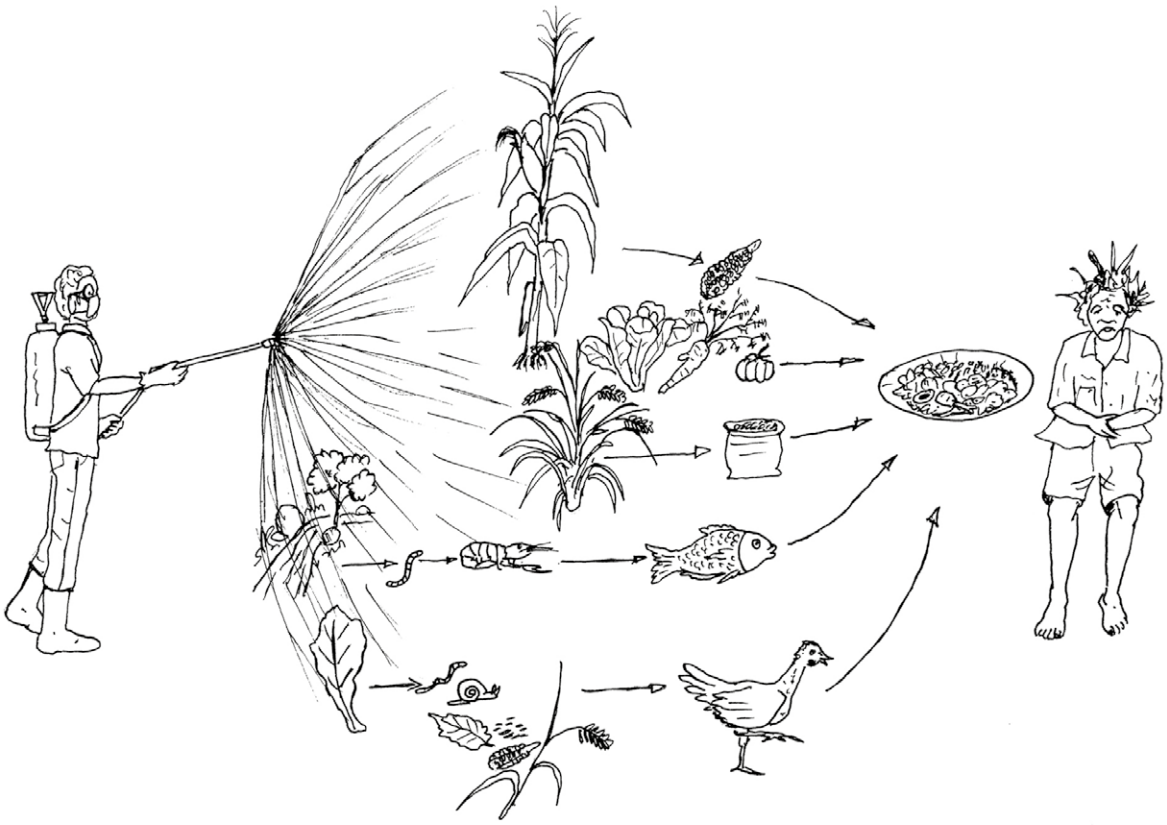
Chemical pesticides, herbicides and fertilisers damage your land and the surrounding environment.

They provide only short-term solutions and cause problems that only get worse the more you use them. Chemicals damage the soil because they kill the soil bacteria and animals. The result is that your agricultural land is less productive and develops erosion problems. Rivers and oceans become polluted from pesticides, herbicides and fertilisers, which also contaminate underground water.

This is a very serious problem because river and underground water is used for drinking and cooking so **must** be kept clean. Fish in ponds and oceans absorb the pollutants, as do water plants.

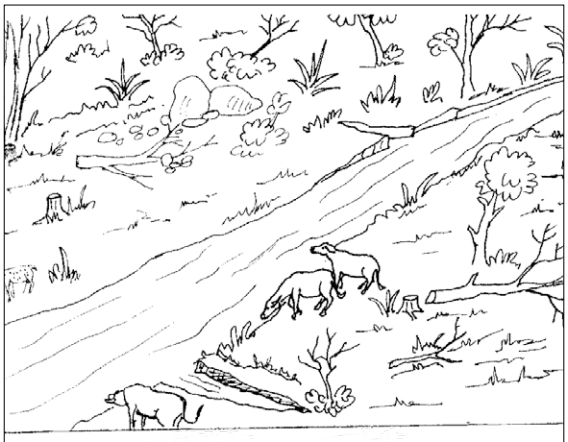
This pollution damages the environment and is also passed onto people, as even the food grown contains small amounts of the chemicals. People who eat the plants and animals, and drink the water, are the worst affected.

Using organic natural fertilisers, natural pest and disease management and mulch means your environment, your food and you are much healthier!

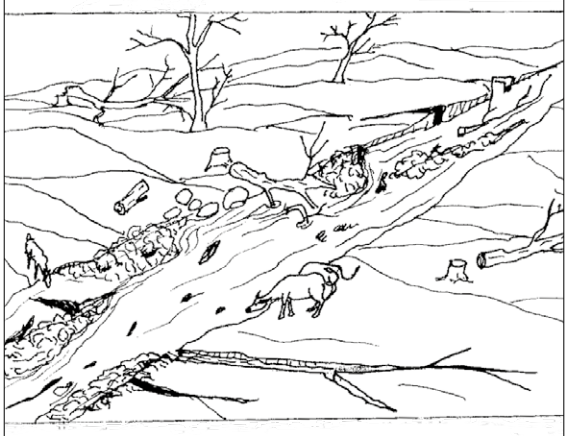


Working together for a healthy environment

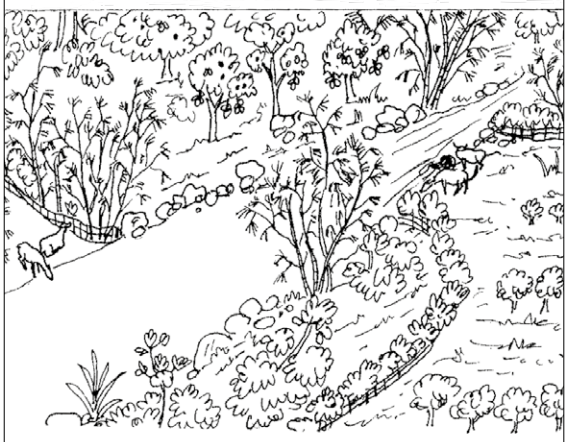
Communities working together can repair and protect the environment, and care for valuable resources at the same time. Cooperation, not competition, is an important basis for working together, achieving community goals for sustainable agriculture and for protecting the surrounding environment.



Present day



Future with bad environmental management



Future with good environmental management, protects the river and agriculture too

Environmental care is very hard to achieve when people work alone. The environment must be looked after at the community level and the national level. Communities can work to protect their environment by stopping erosion and land burning, reforestation, protecting rivers and cleaning up and recycling rubbish.

Ceremonies, such as *Tara Bandu* (a traditional ceremony to protect the land, plants and animals) in Timor-Leste, represent cooperation between people and their environment and protect community land from damage. Read Trees (**Ch 15**) about *Tara Bandu*.

If many communities practise environmental care, working to repair and improve their own land and the environment, the benefits multiply for everyone.

At the national level sustainable and regenerative agricultural techniques must be encouraged and developed by considering:

- Infrastructure for efficient transport and marketing
- Information and training about regenerating damaged soil and restoring natural biodiversity
- Information and training about sustainable, organic agriculture
- Post-harvest storage
- Support for local farmers groups and community cooperatives
- Value-adding projects, for how to develop an existing local product
- Reforestation and protection of the forests and natural environment
- Using well-researched and appropriate biological controls for pests
- Appropriate machinery hire

Improvement in agricultural methods to create sustainable systems is essential for future prosperity. Protection of the natural environment also must take place. These two goals can be achieved together if good designs, strategies and techniques are used.

Creating sustainable agriculture

The methods for creating a sustainable system are divided into the following:

- Resources for sustainable agriculture
- Creating the right conditions
- Land and crop management
- System of Rice Intensification (SRI)
- Working together

Resources for sustainable agriculture

1. SEEDS

Saving, using and improving good quality local seeds are all very important, providing a secure base for farmers and communities. When farmers lose control of their seed supply, they lose control of their livelihoods and independence. This happens especially when commercial seeds are sold as a package with pesticides and herbicides and require their use to produce a good crop.

Non-hybrid, open pollinated seeds are best because the types of seeds stay the same, and the quality improves when good seed-saving techniques are used.

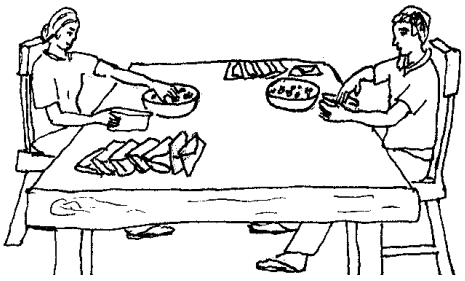
Collecting local seed

Hybrid seeds (not F1 Hybrid types) can usually be used for seed saving; however, they can vary in their characteristics, and the results for the next crop are unknown. The seeds have not adapted to the local conditions and may suffer problems as a result, but they can get better over time if you use good seed-selection techniques.

F1 hybrid and Genetically Modified (GM) hybrid seeds can never be used for seed saving.

The benefits of local seeds:

- Increase the natural pest and disease resistance of the plants
- Perform better in local soil and conditions
- More adaptable to extreme weather conditions resulting from climate change
- Grow well with organic, sustainable agricultural methods
- They are **free**!



Packaging local seeds

Save some seeds from the **best** plants of each crop – the highest yield, most resistant to pests and diseases, best tasting and most resistant to weather extremes – so the plants become more used to the local climate, soil and conditions. Future crops, therefore, will grow better and produce more.

It is good to refresh your seed stock every few years to keep the stock healthy and productivity high. To do this you need to cross pollinate your existing seed stock (90%) with proven good quality seed stock (10%) from somewhere else.

Important factors for seeds:

- Good seed storage is very important to ensure a continuous seed supply.
- A community/farmer seed-saving group ensures more variety and better quality seeds for all members of the group.
- A community seed bank provides a secure supply of local seeds, especially in emergency situations.

Read the chapter Seeds and propagation (**Ch 11**) for detailed information.

2. NATURAL FERTILISERS AND SOIL IMPROVERS

Healthy, living soil is the basis for good agriculture. It is your best protection from problems caused by climate change.

Sustainable agricultural practice must focus on:

- Building up the amount of soil
- Retaining the soil and preventing erosion by rain and wind
- Improving the soil structure and the amount of micro-organisms
- Stopping burning because it prevents achieving these goals

There are many ways to achieve these targets using organic and sustainable methods.

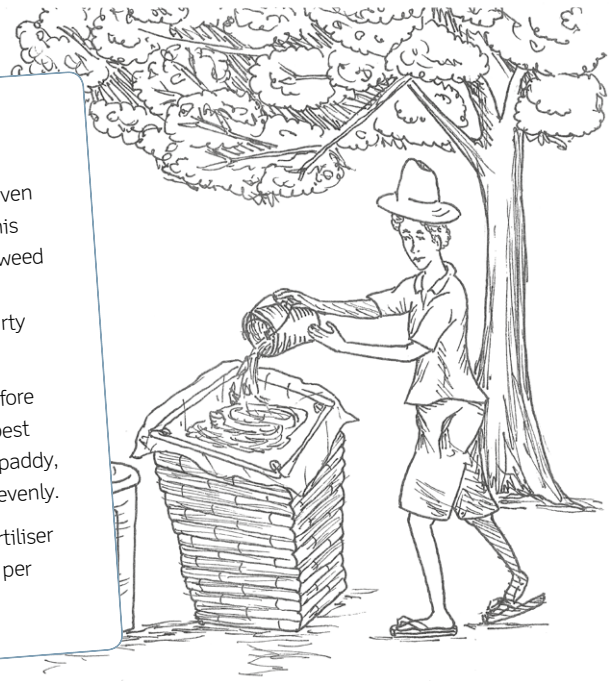
Biodynamics: In many countries, especially where cow manure is available, biodynamic techniques are being used and providing good results. There is a lot of information on the internet and if there are local farms or demonstration/education sites near you, take the opportunity to learn about biodynamics. See Soil (**Ch 9**) and the **Volume 1 Reference chapter**.

Liquid fertiliser

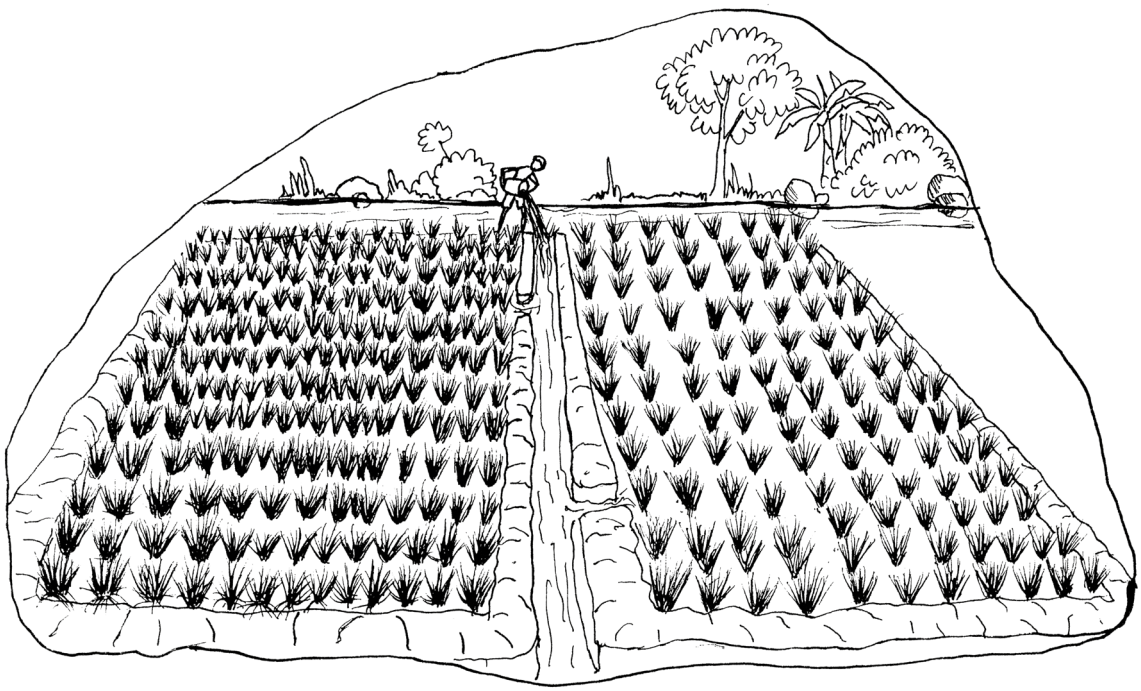
Liquid fertiliser is a great way to make concentrated nutrient-rich, biota-rich organic fertiliser from small amounts of manure and other ingredients. It is excellent for sustainable agriculture and a much more efficient use of materials, time and space than compost. Always use liquid fertiliser with mulch, especially if you do not use compost.

SMART IDEAS:

- When used on large areas liquid fertiliser can be made even more concentrated so you can spread it further. To do this use chicken, duck, bat or pigeon manure, add more seaweed and double the amount of wood-fire ash. If you make it stronger, make sure you dilute it with more water, at thirty parts water to one part liquid fertiliser.
- Liquid fertiliser can be added to rice paddies. Use it before planting, during growing and after harvesting for the best results. Use approximately one bucket of fertiliser per paddy, mixed with one or two buckets of water and spread it evenly.
- If your croplands are flood irrigated, add the liquid fertiliser straight into the irrigation water. Use about a bucket per 10 x 10 metres, and apply once or twice a month.



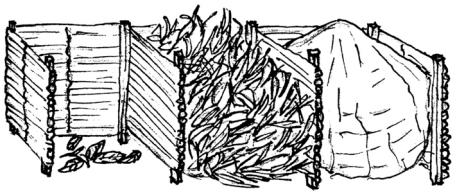
Read the Soil chapter (**Ch 9**) for how to make and use liquid compost.



Adding liquid compost to rice paddies

Compost and manure

Compost and manure are excellent for supplying nutrients and improving soil quality. Read Soil (**Ch 9**) for detailed information. On large areas of land it is difficult to make enough – mulch and liquid fertilisers are easier – but it is still good to add as much compost and manure as possible. It is much easier to collect and use large amounts of manure and compost if animals are housed at night.



Animals can be fenced or tethered on the cropland in the dry season or in between crops to provide manure.

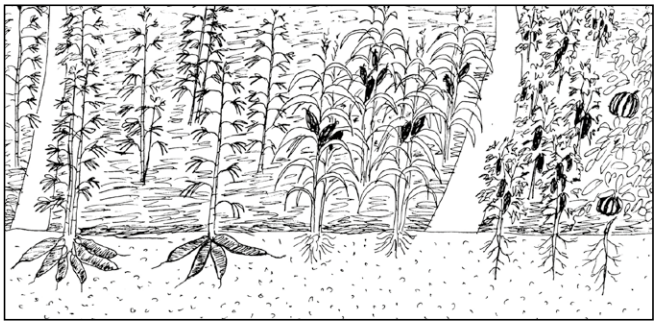
Mulch

Mulch provides many, many benefits for your cropland.

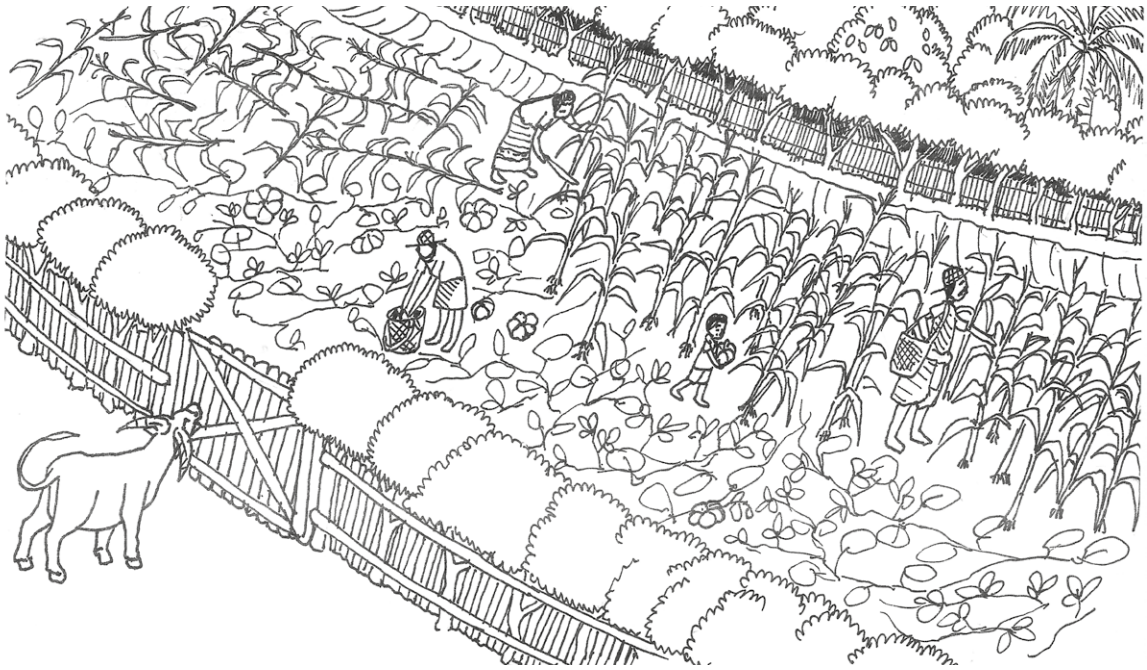
Use the crop waste for mulch instead of burning it, because this provides nutrients for future crops. The soil is greatly improved because the mulch also provides organic material and food for soil biota (animals). Add a bacterial activator to help the mulch break down faster.

Water stays in the soil for much longer, erosion is greatly decreased and soil micro-organisms are protected. Nitrogen also stays in the ground: if soil is exposed in very hot weather, nitrogen can turn to gas and leave the soil.

Apply mulch continuously and as thickly (5–10cm) as possible. Read detailed information about mulch and bacterial activators in the Soil chapter (**Ch 9**).



Grow as many mulch-producing plants on your farm as possible. Most of these plants also provide food and other products: e.g. legume trees, bamboo, vetiver grass, green manure crops.



Using crop waste and living fences as mulch

Cover crops – living mulch

Cover crops grow along the ground, thus 'covering' the surface. They are crops with three important functions:

- Adding nutrients and organic matter to the soil
- Weed control because they prevent many weeds from growing through reducing light
- Erosion control

In Timor-Leste the 'Slash and Mulch' system was introduced and trialled by agricultural lecturers at the national university. Beans planted half way through the corn-growing cycle cover the ground in between the corn crop. The beans do not compete with the corn, as they are planted later, and they provide good weed control and food for the soil. The beans are also cut back for mulch, as are the corn stalks. In the trials sword bean (Canavalia gladiata) and jack bean (Canavalia ensiformis) were used with good results.

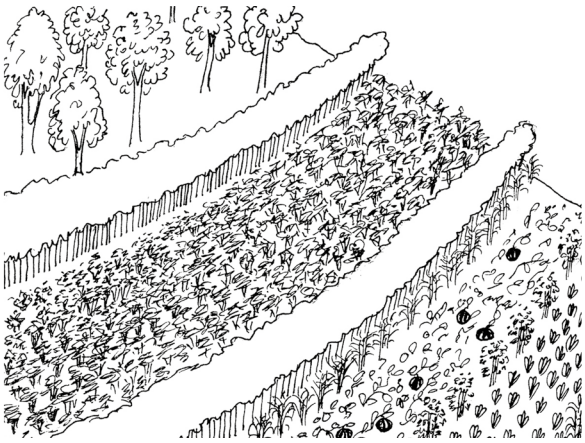
Other plants can be used as cover crops including other beans, pumpkins, gourds and sweet potatoes, although crop yields are reduced when they are used as cover crops.

There are many other legume cover crops, including pinto peanut, calopo, cow pea, desmodium, vigna spp., lablab bean, crotalaria and centrosema spp. They are excellent for improving soil, adding organic matter, creating mulch, providing produce, and some are also good for feeding animals.

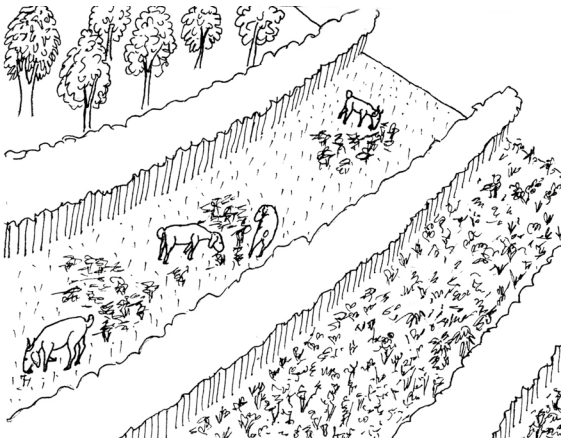
Careful: They can also become bad weeds! Use local varieties and/or varieties that are proven not to become weeds in your region.

Green manure crops

Green manure crops provide nutrients, organic matter and mulch. Read the legume section in Soil (**Ch 9**) for how to grow a green manure crop. They can also be non-legumes, and work best when a mix of plants are used. Green manure crops on sustainable agricultural land can be grown in rotation with other crops or intercropped. They can also be grown in rotation with animals.



Green manure crop



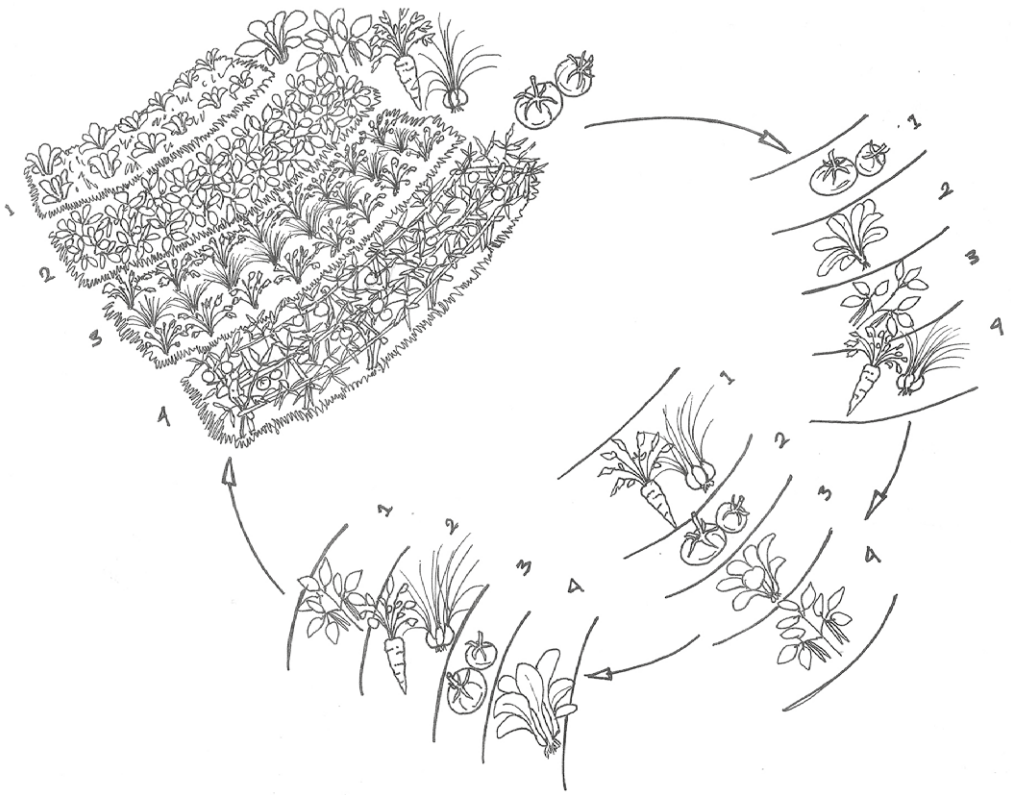
Animals eat green manure crop

After you harvest the main crop (e.g. rice or corn), you can plant a green manure crop. Then:

- Cut the crop back when it starts to flower and use it as mulch

OR

- Bring in animals just before the green manure crop starts to flower and they eat most of it. The crop provides nitrogen and some organic matter for the soil and the animals provide manure.



Green manure crop as part of a crop rotation system

Bacterial activators

Bacterial activators increase the amount of micro-organisms in the soil. This improves the soil quality and increases production. They are especially good for large-scale production because:

- They are easy to use on a large area of land.
- They can be combined with any type of organic fertiliser, liquid fertiliser and mulch.
- With good land management they naturally multiply in the soil. Read the Soil chapter (**Ch 9**) for how to make and use bacterial activators.

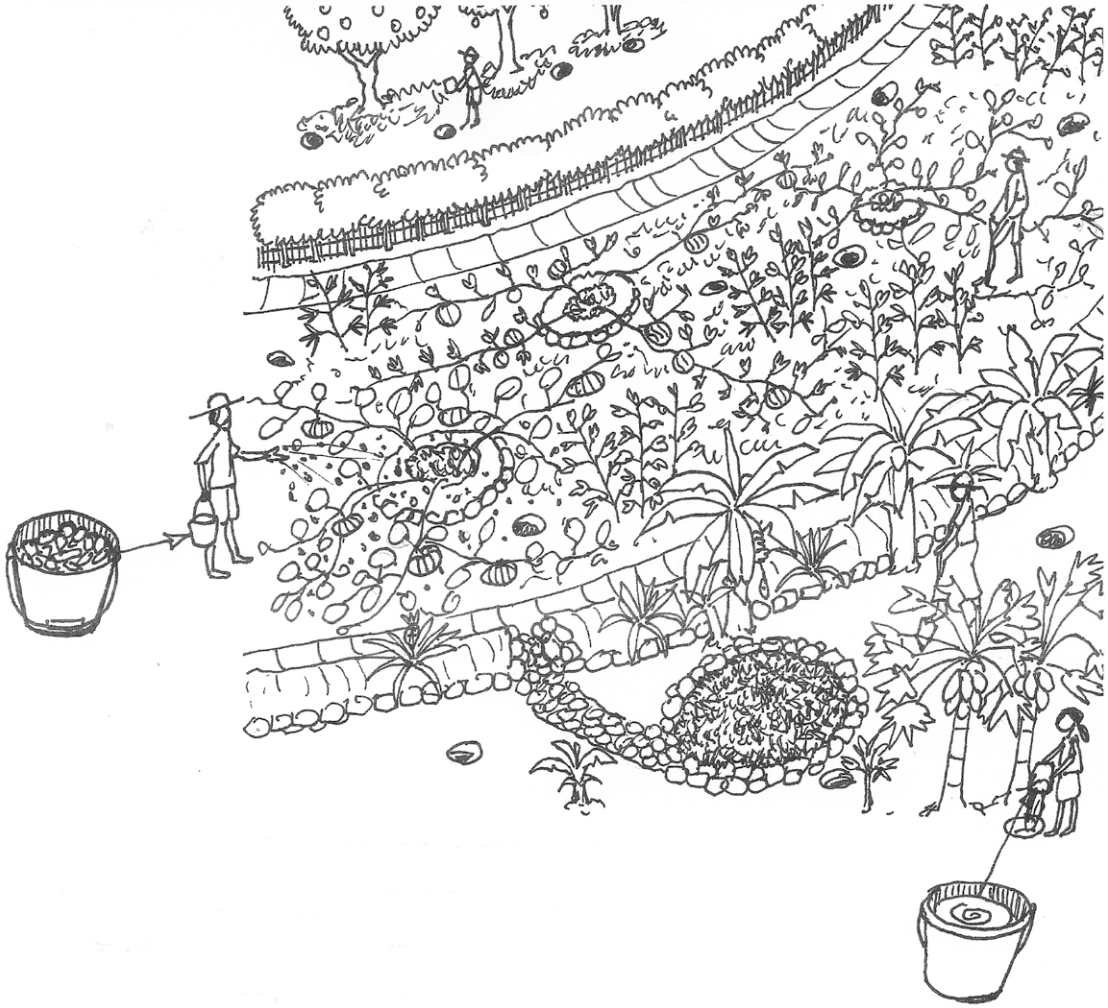
Biochar

Biochar is one of the most important 'new' technologies for sustainable agriculture. It has been used for a long, long time, but it is only now that scientists and farmers worldwide are testing it and realising how beneficial it is.

Biochar is specially prepared charcoal that has been soaked in a nutrient and micro-organism-rich liquid, and added to the soil. The most important benefit is that once it is applied it keeps working for you, for your children, your children's children, and their children too!

Biochar provides carbon for the soil, and acts as a 'house' for holding nutrients, micro-organisms and good bacteria. It also greatly improves the water-holding capacity of the soil. The result is that nutrients stay in the soil in the wet season, and you use less water in the dry season.

There are many more benefits. Read about them and how to make and use biochar in Soil (**Ch 9**).



Spreading biochar and bacterial activator

Legumes – annual

Annual legumes are a vital resource for sustainable agriculture and are used mostly as cover crops, green manure crops and mulch producers. See the sections above.

Legumes – perennial

Many legume trees – such as leucaena, acacia, gliricidia, calliandra, pigeon pea, albizia, sesbania, crotalaria and more – can be grown around croplands, on terrace edges, rice paddy edges or in rows to provide mulch. When the mulch is cut the legume trees provide nitrogen from their roots, and reduce damage from strong winds. Read Soil (**Ch 9**) and Trees (**Ch 15**) for more about using legume trees.

Mulch and compost material, from legume and other trees, is high in nutrients and minerals. In tropical regions a lot of the nutrients are stored in the trees and leaves, and not in the soil. Therefore, they are excellent for mulch and composts, and should not be burned!

Integrated crops with legume tree terraces

3. WATER SUPPLY

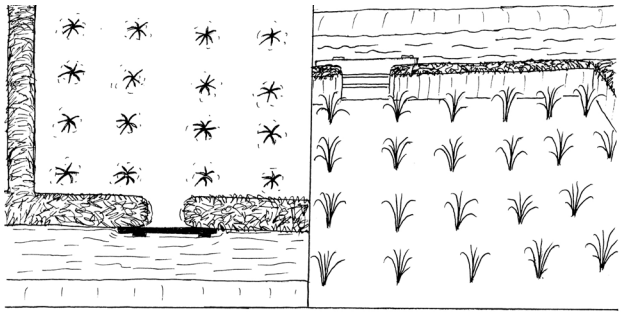
Irrigation

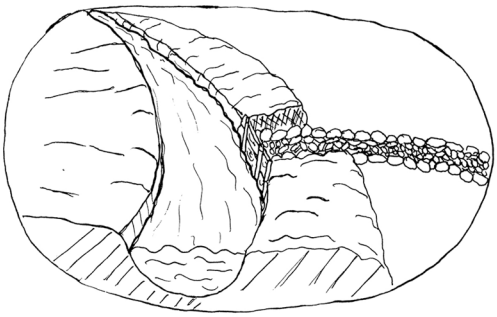
Irrigation can:

- Provide water in dry periods of the wet season
- Extend the wet season
- Channel the wet season rains to where you want the water
- Provide a separate irrigation system from a pump or water source that irrigates cropland even in the dry season

Irrigation of large crop areas takes a long time to set up and can be expensive, so it is important to **make a plan**. It is always good to start small but think about what you will want in the future. Observe where the water flows through your land. Plan for where you want irrigation on your land and for future needs. Try to combine different crops and areas, and plan for how to use excess water from one area to irrigate another area. Work together with your neighbours and community: this makes irrigation cheaper and easier to maintain. A community water-users group is a good way to manage irrigation and water use.

Paddy irrigation and trench-flooding irrigation are the most common types. They are good for the wet season but, in many places, they use too much water to be effective in the dry season. Water gates can reduce the amount of water needed, which means that not all paddies or trenches get flooded at once. The gates can be on the irrigation channel or from paddy to paddy.





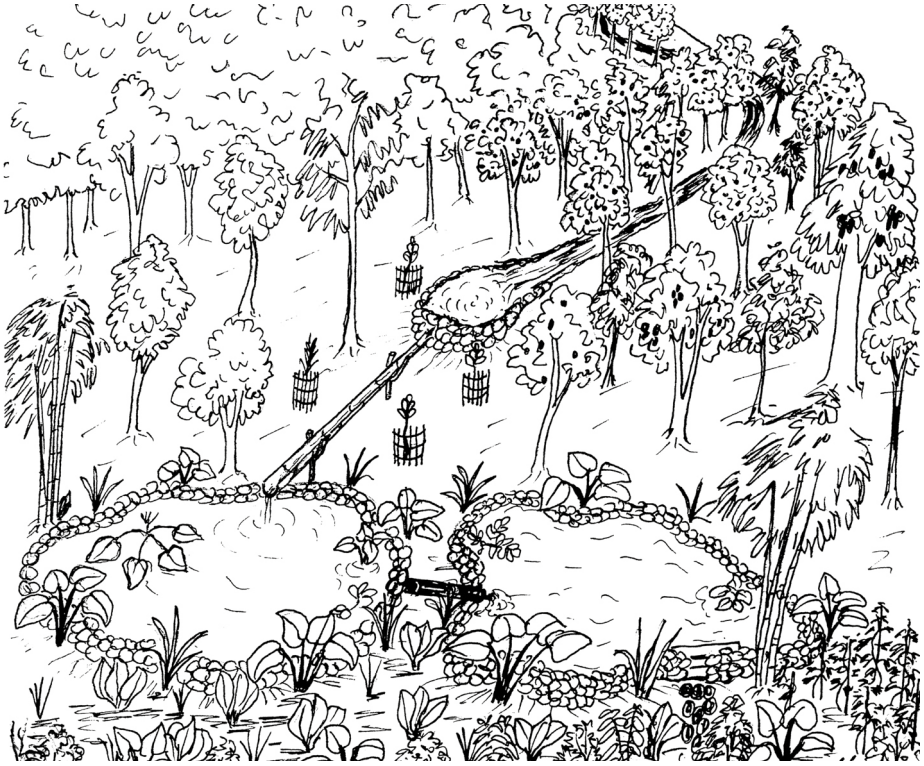
The water is directed where it is needed, but requires a constant source. Swales and water-trenches can be used for irrigation and can evenly run water down a slope. They can be easily combined with aquaculture ponds and take water to rice paddies, croplands, market gardens, etc. If you use swales for irrigation, make sure the overflow point is well made to stop erosion. Rocks or a simple gate can be used to regulate the flow of water.

Making multiple uses from irrigation water

Water catchments and small dams

To have a secure water supply for irrigation, building water catchments and dams is vital and worth the time and, sometimes, the money needed to make them. Not all land is suitable for holding water but, even so, water storage is still possible.

Creating water catchments is not simple, especially constructing small dams, and should only be done by people with the knowledge and experience. If they are made in the wrong place, or not made strong enough or with the right materials, big problems can occur, and a lot of time, resources and money are wasted.



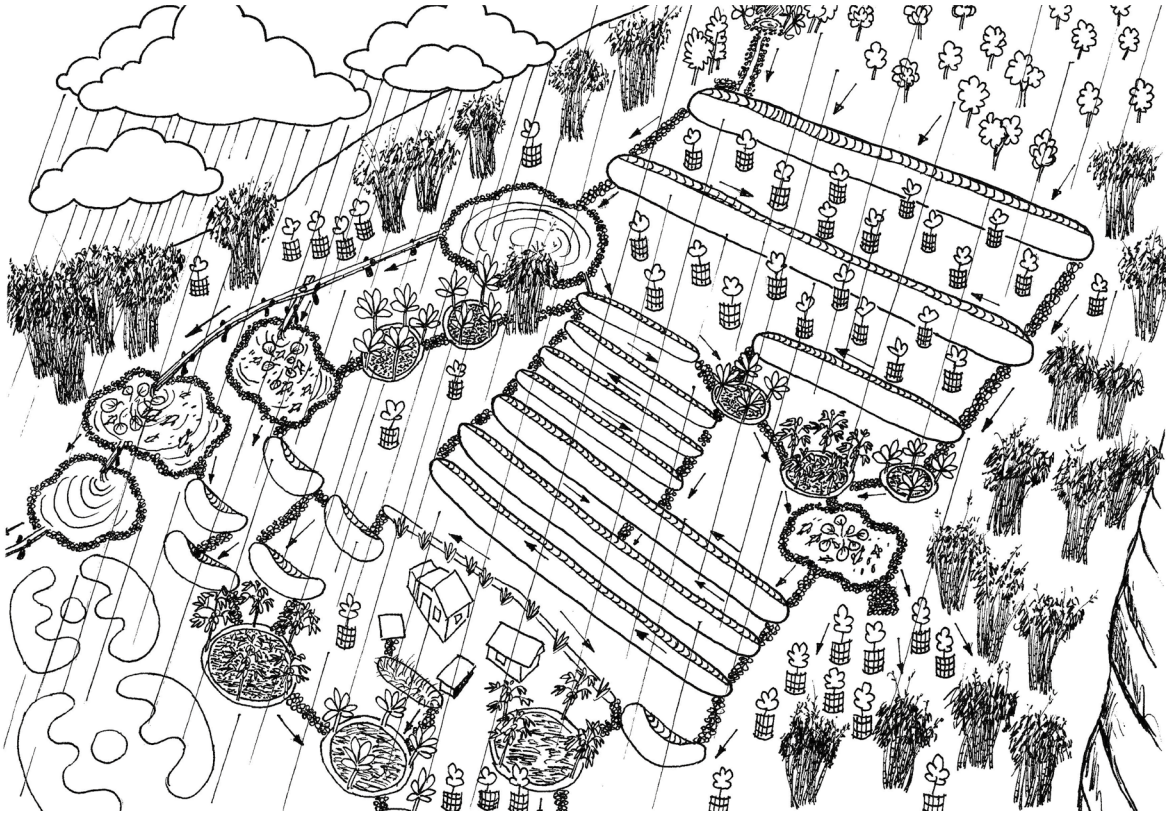
For every water catchment:

- Decide how much water you need and where you need it.
- Survey the land and where the water moves.
- Test the soil to find out if it can hold water.
- Make a design that suits the land, provides your needs and can work with extreme weather events.

Important ideas to include when making a design:

- It is always easier to move water down a hill or slope. Therefore, place the water catchments as high as possible and above your agricultural land.
- Smaller catchments are easier to make and manage than large ones, but large ones are better for long periods with no rain. A design can include both, if the land is suitable, but not a catchment so big that it removes, damages or destroys a lot of natural environment.
- The slope of the dam walls should be approximately 45 degrees to make them as strong as possible.
- **Always** connect water catchments together via overflow points and use swales, trenches and other methods to catch and move water to the water catchments.
- The small dam/water catchment walls and overflow points must be very secure and able to cope with extreme weather events.

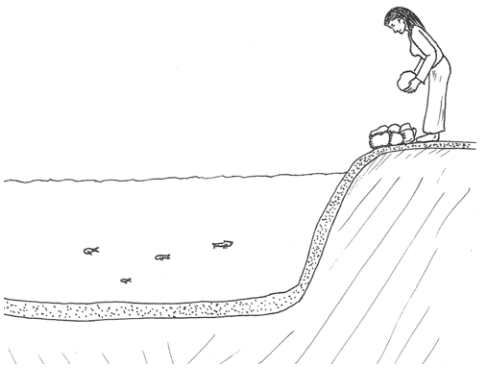
- Use appropriate trees, grasses, bamboos and other plants to secure the soil and prevent erosion around the dams and water catchments, but **do no** plant trees directly on the dam walls.
- Make use of the water caught and stored in the ground, especially along the swales and trenches. These are highly productive areas for fruit trees and other plants.
- Water catchments can sometimes be combined with aquaculture.
- Mosquito prevention techniques – such as small fish or using neem oil – **must** be used.



Use strong plastic sheets in areas where the soil does not hold water. Line the ground beneath the plastic with sand or fine soil first and remove all the rocks, or the plastic quickly gets holes and loses water.

Look in the **Volume 3 Reference chapter** for more information, and always work with people who have experience in building dams or water catchments before starting.

Small dams in rivers, in appropriate and minimal risk places, can be very useful in very dry tropical regions. They can provide water for animals, birds and insects for a few extra months and help to spread water into the ground around the dams. Grow trees and plants which provide food, shade and habitat. Take care to make the dam walls very strong, and create spill holes for the water to run through below the walls to protect them from erosion. Do not plant any trees on the dam walls, only use bamboos and grasses. The trees can grow roots through the walls and they rot and die from too much water, which then creates holes in the dam walls.



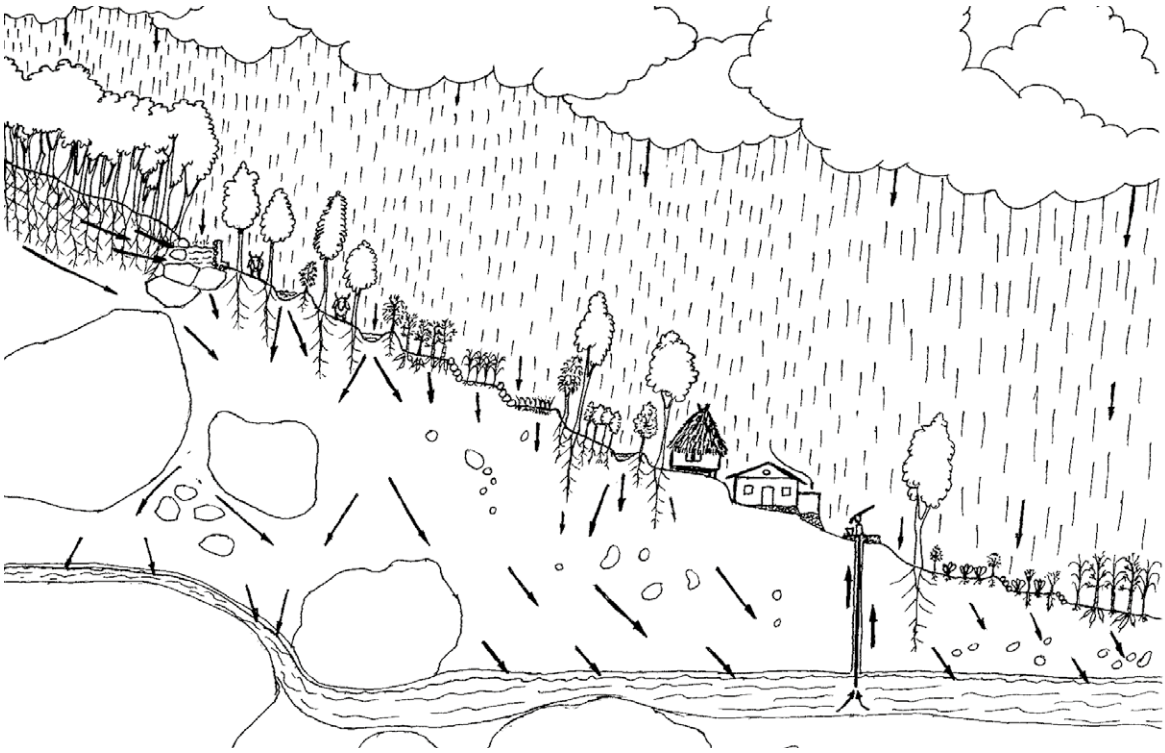
Underground water

In many tropical countries, underground water supplies are being used much faster than the water is replaced. This is already causing big problems and will only lead to disasters such as salty water and no water supply.

Steps must be taken to reverse this problem:

- All techniques to reduce water use on agricultural land must be applied:
  - Stop flood irrigation.
  - Improve soil so it can hold much more water. Healthy living soil holds 50% more water!
  - Use mulch.
- The mountain and hills above agricultural land must be repaired:
  - Swales, terraces and water catchments catch and store rain in the ground.
  - Tree crops and reforestation stop erosion and hold the water.
  - Stop burning.
  - Repair and protect all rivers and waterways.

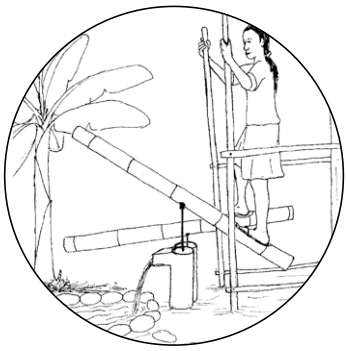
There are many successful examples which show that when rainwater is caught, channeled and stored using good techniques, underground water supplies increase and the land repairs quickly.



Cross section illustration of slowing, storing and spreading rainwater on a slope

Peddle pumps and animal-driven pumps

These pumps are cheaper, require no petrol and can be maintained and repaired locally. There are many different examples. As they require more effort to use, people are more careful and efficient with the water use. Read Houses, water and energy (**Ch 7**) for more information about them.



Treadle pump for irrigation

Creating the right conditions

The following strategies and techniques enable you to improve the agricultural land AND to use the land around your croplands to improve crop production and protect your land for the future.

They are important for starting new farms and even more so for improving existing farms. They can be used on family land, with many families together, or on community land.

1. LAND DESIGN USING NATURAL PATTERNS

Follow the natural patterns of the land and integrate them into your land-use design. The Permaculture design strategies and techniques chapter (**Ch 3**) will guide you, especially the site analysis section.

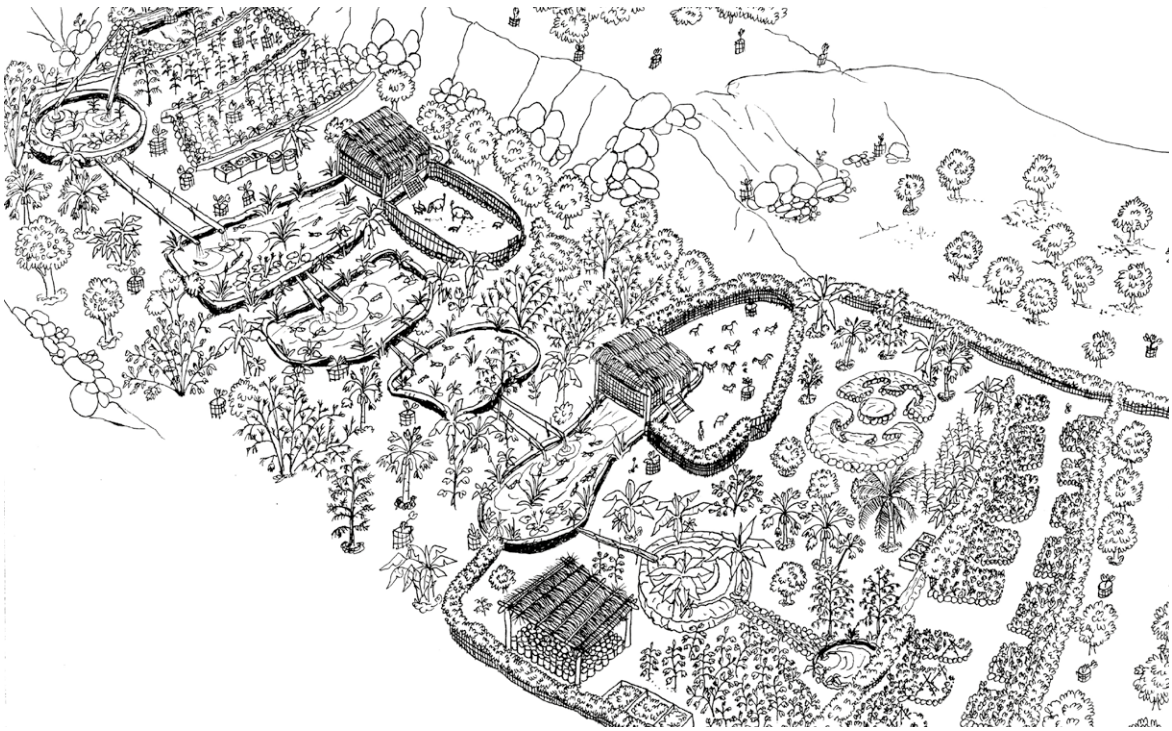
Observe and consider:

- The natural shape and slope of the land
- Water flow and sources
- Access – good access reduces soil compaction and water run-off
- Soil quality
- Sun direction
- Wind direction
- Flood zones
- Fire direction

By using the results of the site analysis and applying a permaculture design, you can create and implement a sustainable and efficient system. This maximises productivity, while reducing water use and preventing many potential problems.

Water catchments, including terracing and swales, are good examples of using the natural pattern to create productive land. Working with nature and natural patterns:

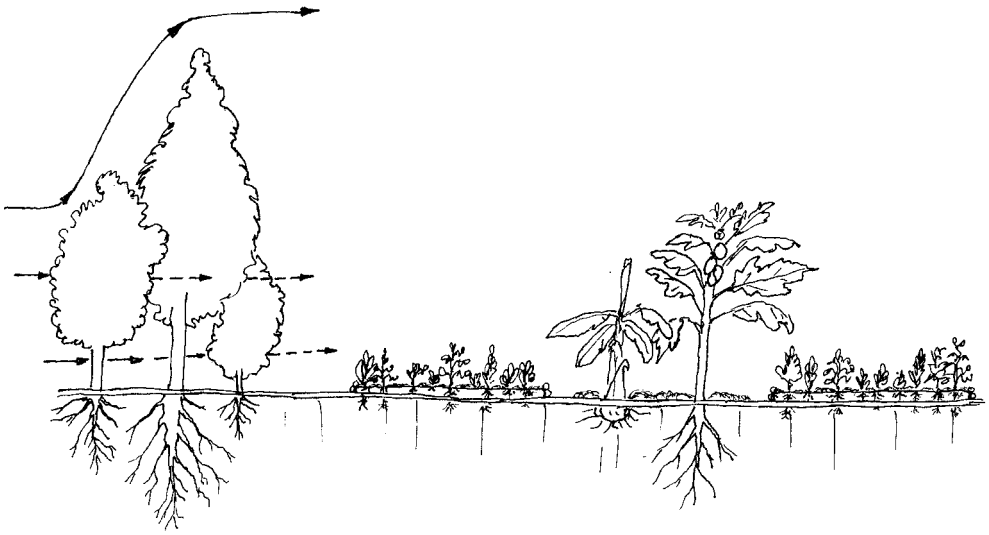
- Reduces labour and resources needed
- Maximises the productivity of sloping land
- Greatly improves the long-term sustainability of your land



Example of land design combining water storage, aquaculture, animals, tree and annual crops

2. WINDBREAKS

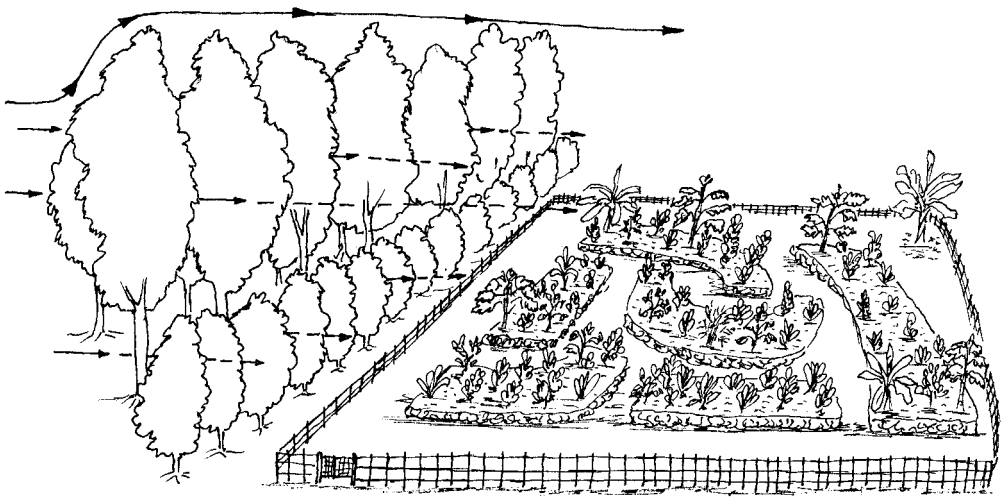
Strong winds cause a lot of damage to crops and remove valuable topsoil. A windbreak slows and redirects strong winds while still allowing light winds to blow through.



Windbreaks are especially important for places where strong winds continually blow for many months of the year. **Even a small windbreak improves production for a large area of land.**

Direct benefits of windbreaks for agriculture:

- Reducing stress on plants increases growth rates.
- Reduced wind damage to plants
- Reduced erosion from the wind removing the topsoil
- Water evaporation from plants and soil is much less, and plants use water more efficiently.
- Soil temperatures do not change as much – the soil does not get as hot or cold. This creates better temperatures for healthy plant roots and soil biota.
- Pest and disease problems are reduced because plants are less stressed.
- Pollination rates increase because more birds and insects are attracted to the windbreak trees. This increases the number of grains, vegetables or fruit on each plant.
- The nitrogen in the soil increases around the windbreaks, and on land below them, if you use a lot of legume trees.



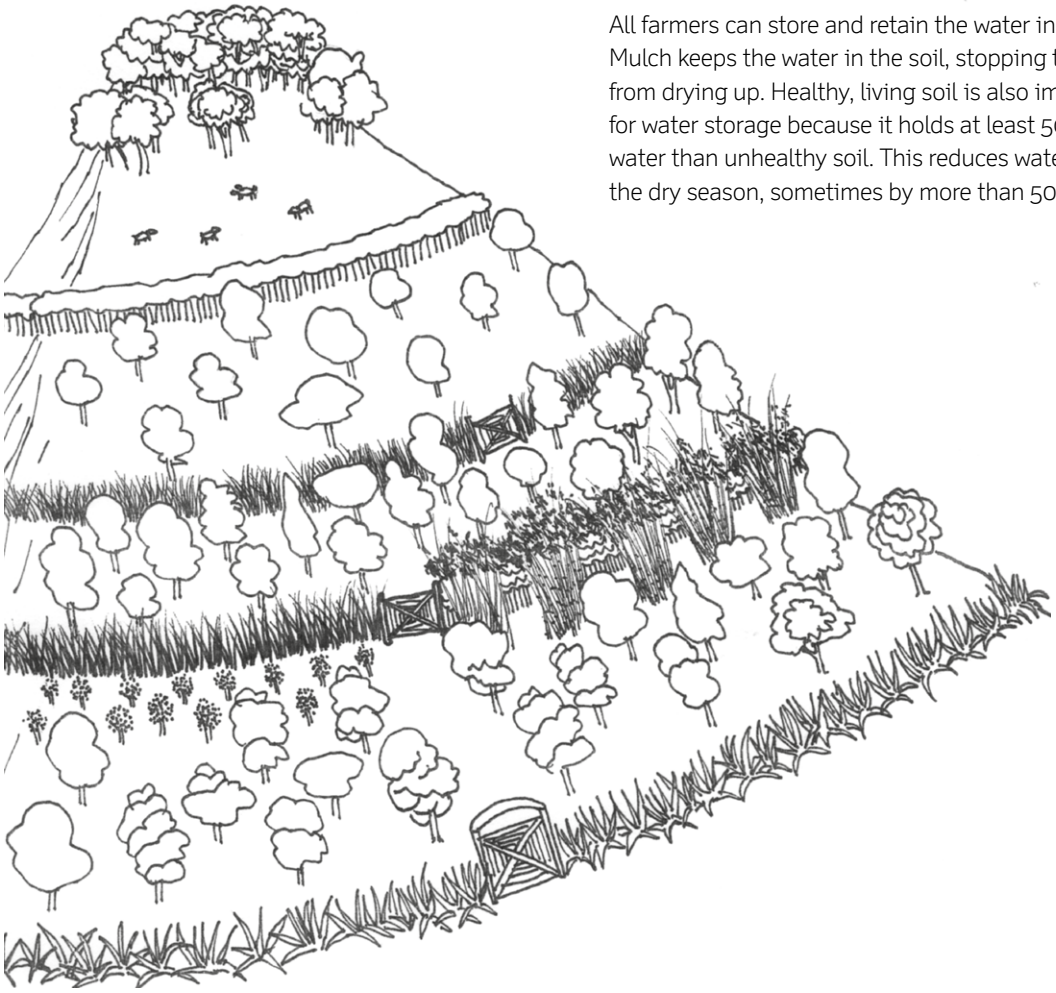
Read Permaculture design strategies and techniques (**Ch 3**) about how to design, create and manage windbreaks.

3. TERRACES AND SWALES FOR WATER STORAGE AND SOIL PROTECTION

For agricultural land

It is vital to protect the soil so the volume increases and the quality improves each year. On sloping land design and build systems to protect your soil, such as swales, terraces and tree terraces. Choose the method and design that best suit your needs and situation.

For most farmers, large crops are dependent on rains. Therefore, most of the vegetable and grain crops are only grown in the wet season. There are techniques that can make the wet season crops more consistent with higher yields, and sometimes enable dry season crops to be grown where they previously were not.

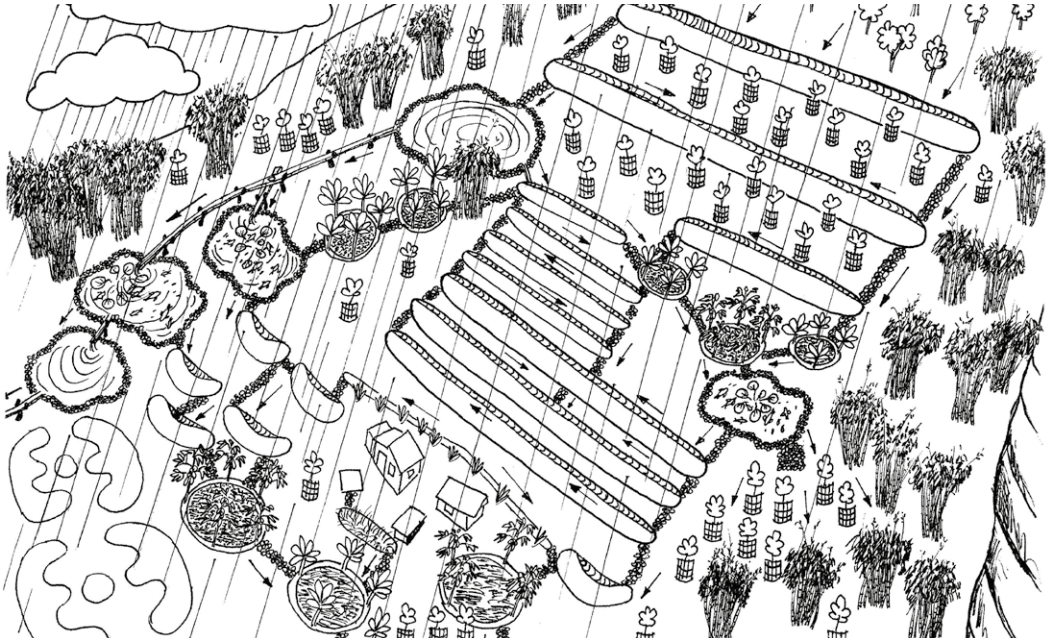


All farmers can store and retain the water in the soil. Mulch keeps the water in the soil, stopping the soil from drying up. Healthy, living soil is also important for water storage because it holds at least 50% more water than unhealthy soil. This reduces water use in the dry season, sometimes by more than 50%!

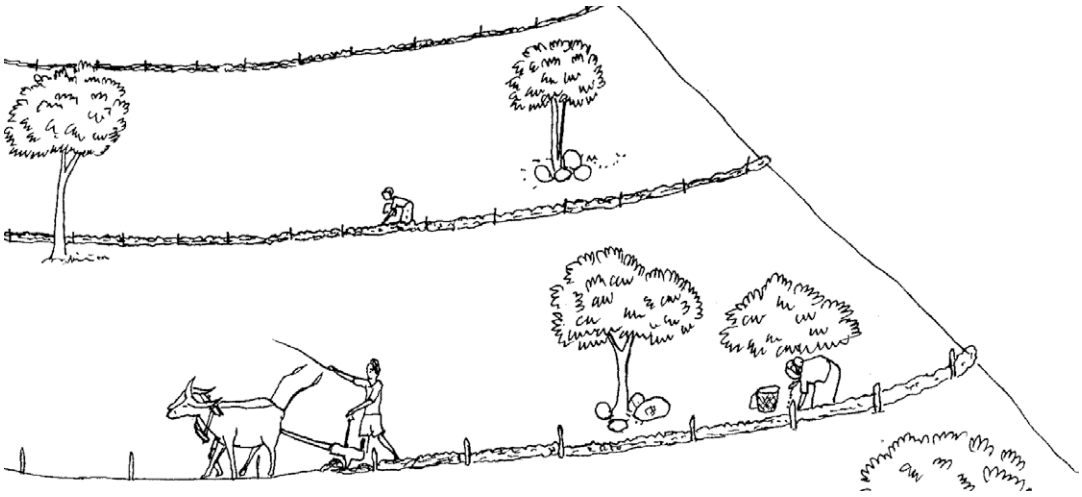
For mountains and sloped land, swales and tree terraces catch and store water. Even gently sloping land holds a lot more water if swales and tree terracesare used. Rainwater enters the soil and increases underground water storage, which feeds natural springs and underground water supplies. Read Permaculture design strategies and techniques (**Ch 3**) for how to make and use tree terraces and swales.

When you have a good swale or terrace system in place it controls where the water from rain and irrigation goes:

1. The system catches, spreads and stores water in the ground where you want it. For most types of rain this means all of the water. The soil just below each swale or tree terrace is always the wettest.
2. For heavier rain the system allow excess water to flow through and out of the system without causing erosion and damage, while still retaining and storing most of the water.
3. For very heavy rain the swales allow the rain to flow out of the system where **you** want it to go without causing damage or flooding.



Tree Terracing (or Living Terracing) is an excellent method for improving production, improving soil quality, storing water and stopping erosion.

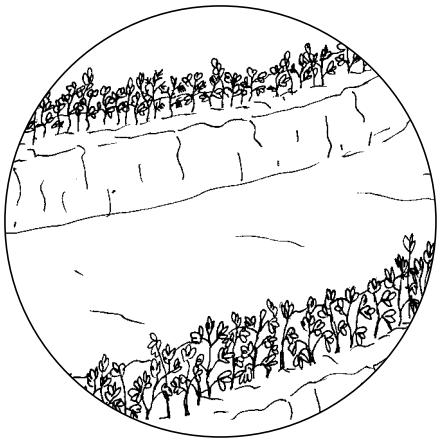


Ploughing contour lines in preparation for planting tree terraces

The process involves:

- Marking out contour lines, approximately five metres apart on gentle slopes, and two to three metres apart on steep slopes
- Digging small swales on the contour lines
- When the wet season begins, plant out legume seeds on top of the swales, very close together (10cm apart): gliricidia or leucaena are best.

The legumes grow into a thick fence which eventually creates a terrace. They can be cut back for mulch every one to two months in the wet season, and once or twice times in the dry season.



Tree terraces starting to grow

Vegetable and grain crops are grown between the rows. Read the Permaculture design strategies and techniques (**Ch 3**) and Trees (**Ch 15)** chapters for more information and for integration ideas. Vetiver grass can be grown instead of legumes on some rows. It is very deep rooted, holds the soil together and produces a lot of mulch. It is especially good for steep slopes, but can become a home for rats. Read the **Volume 3 Reference chapter** for more information on vetiver grass.

For protecting agricultural land

Erosion and flooding from the land above agricultural areas cause a lot of damage and destroy crops, animals and even houses.

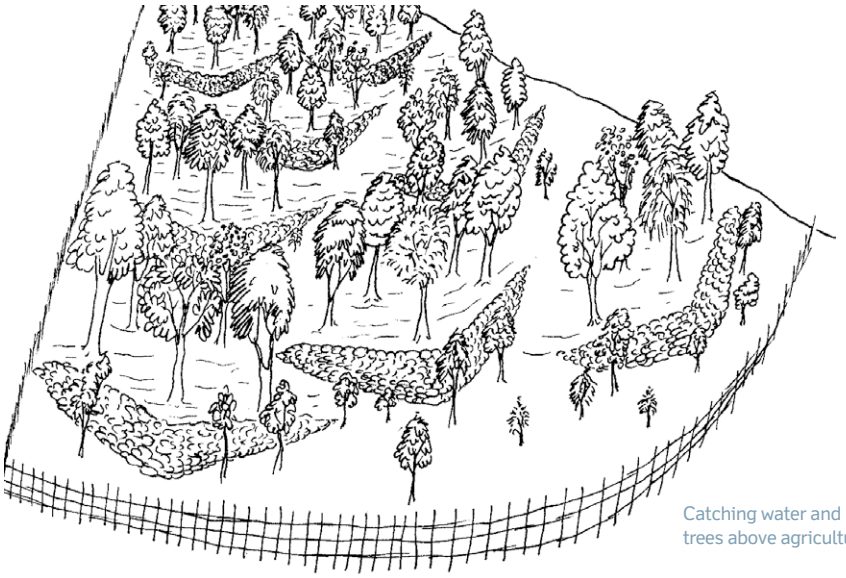
Erosion takes away large amounts of top soil, and it can also enter irrigation canals and rice paddies causing more problems.

Sometimes flooding can be prevented, sometimes it cannot, but the affects and amount of flooding can usually be minimised. Tree terraces, swales and other water storage techniques can be used to catch and store water, allowing it to enter the soil and sub-soil. This minimises flooding and erosion because water is prevented from building up and flowing in large volumes.

Start using swales and water catchments where the water starts building up, as high up the mountains as possible. Always plant out with trees immediately. The loss of trees increases erosion dramatically.

To be most effective, all solutions must happen at community and regional level, with community groups working together. If a family makes swales or terraces on their land, they improve productivity and reduce erosion on that piece of land **and** reduce the flood potential for the land below them.

Read the Permaculture design strategies and techniques (**Ch 3**) and Trees (**Ch 15**) chapters for how to plan and build tree terraces, swales and other water storage techniques.



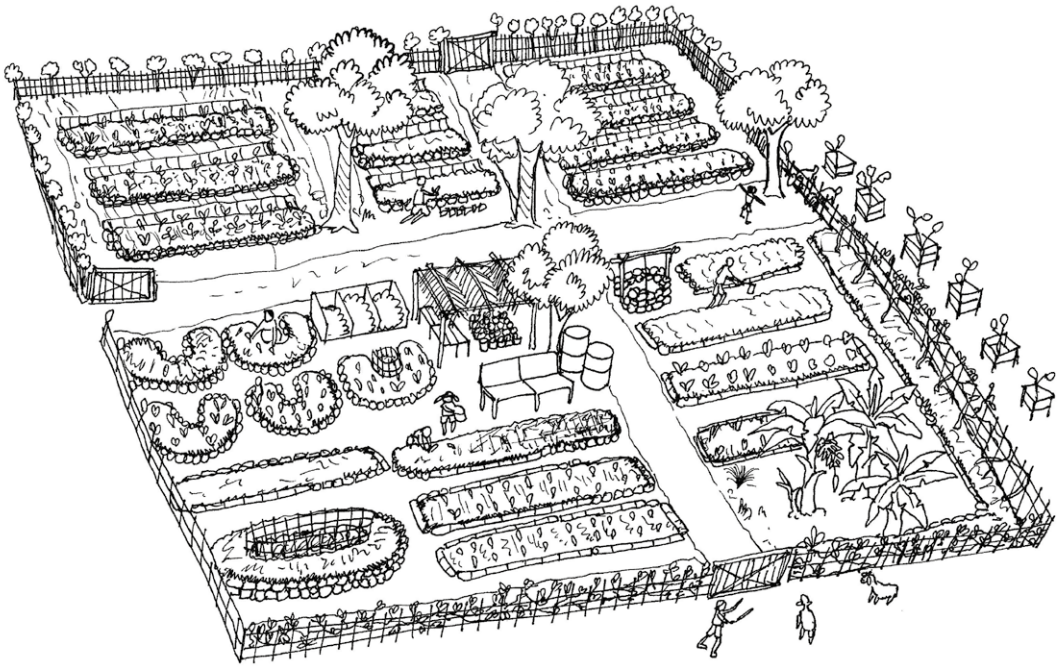
Catching water and planting trees above agriculture land

4. RAISED VEGETABLE BEDS

For growing vegetables raised beds have many advantages over flat land.

There is:

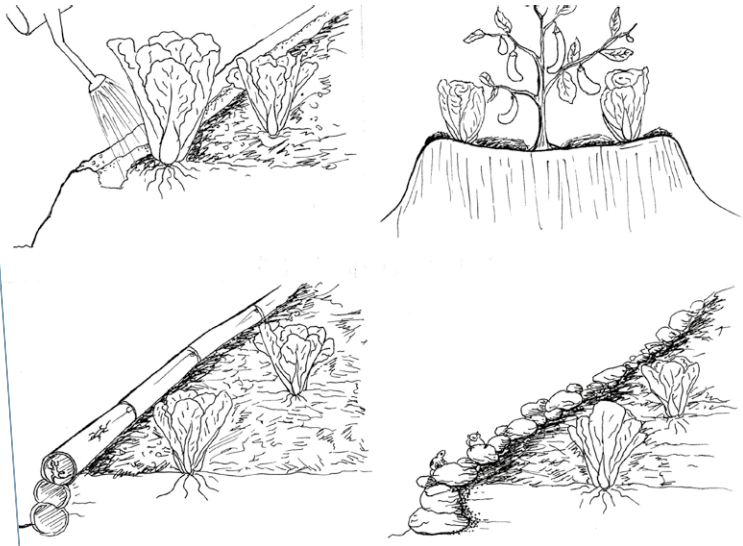
- Less and easier maintenance
- Better water retention in the dry season and less flooding in the wet season
- Much less soil compaction
- Improved quantity and nutritional value of the food produced
- Reduced inputs and costs
- Greater resilience – reducing susceptibility to adverse financial and climatic events
- Less pest damage to crops
- Reduced risk of total crop failure



SMART IDEAS:

Raised beds are even better when:

- They have rocks, bamboo, wood, etc. around the edges as a border
- They have a water-catching edge to hold in the soil, water and mulch
- They are made with a very slight slope to the middle of the bed from the edges with a small drain or compost trench in the middle



5. PLASTIC HOUSES OR ROOFS

Plastic houses or roofs are good for some crops to improve production, especially in mountainous regions, as they prevent problems from rain and pests.

They are expensive and are recommended for market crops or to build as a cooperative/community business. Plants, such as broccoli and cauliflower grow much better and tomatoes fruit better. In colder months some vegetables can been be grown under plastic when they do not grow well outside. Organic growing methods based on healthy soil should still be used. As you are creating a new microclimate with the plastic, careful observation for pest and fungus problems is important, followed by natural control methods if necessary. Ventilation is vital for good production.

A good design for the tropics is to use a plastic roof down to a metre above ground level for two sides, with shade cloth under that to the ground. Both ends are entirely made of shade cloth. The design excludes pests but still allows for good ventilation.

Plastic roofs and houses can create problems if you do not choose the right design or they are not well managed. Some problems include:

- Plastic houses or roofs can be expensive to buy and, if a crop fails, the farmer(s) can be in debt.
- Plants can die from overheating if there is not good ventilation.
- Pest and disease problems can increase from too much humidity or if the plants get stressed.
- Plants never get direct rainwater, which contains many nutrients.
- The plastic ends up as rubbish after a couple of years use.

SMART IDEA:

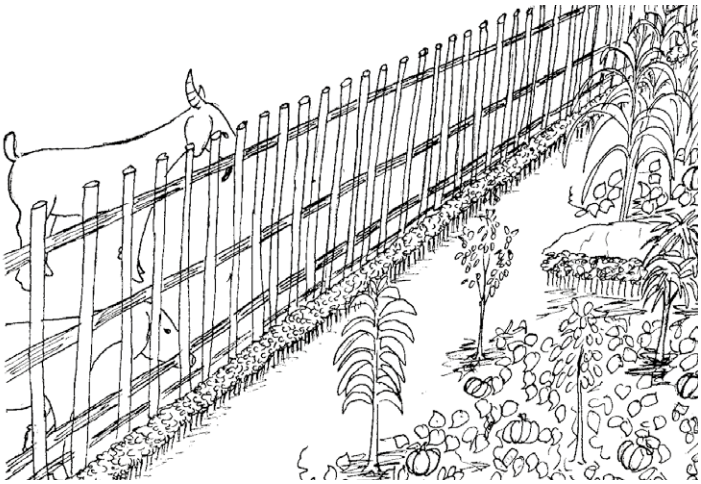
Heavy rain can be moderated with shade cloth roof instead of a plastic roof; a 10–15% thickness gives good protection.

6. FENCES

Fences are very important for protecting your crops. They need to be very strong and well maintained.

If they are living fences they can provide many other functions too:

- Mulch for your crops
- Food for animals
- Food for people
- Material for compost and liquid compost
- Nitrogen for the soil when you use legume trees
- Wind protection but they are not as good as windbreaks. They can be one row of a windbreak.
- If fences are planted on a contour or on sloping land, they catch soil, rocks, mulch and water. This helps protect your soil and improves production.



Fence with living fence starting to grow inside it

The best plants to use are:

- Legumes
- Long-lasting trees
- Cactus plants such as large agave
- Trees that grow back quickly after they are pruned
- Some types of bamboo that start branching close the bottom of the culms

Moringa, gliricidia and leucaena are good examples of trees to use. However, be careful when introducing leucaena and other trees that spread quickly, as they can become a weed problem.

CAREFUL: Chickens can fly over most fences and damage crops, especially when the crops are young.

7. STOP BURNING!

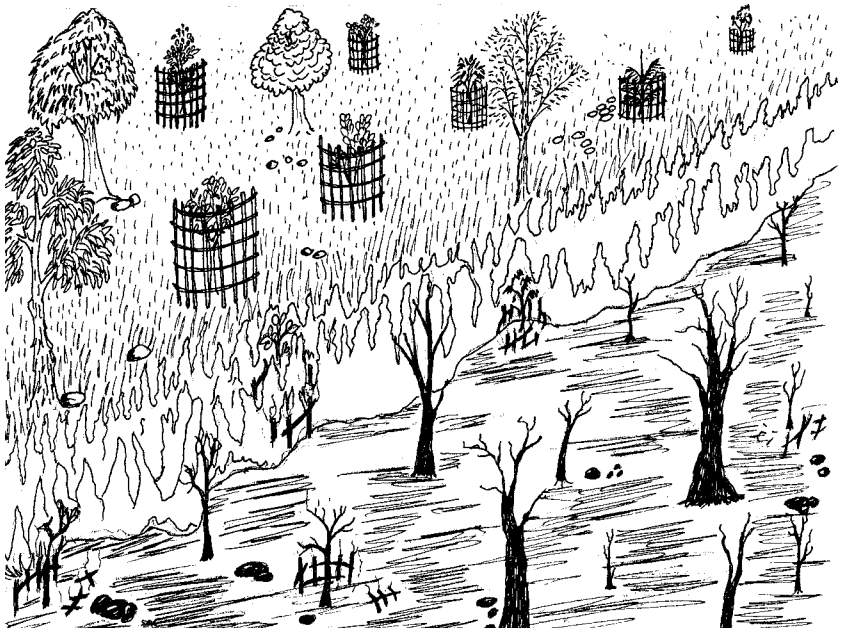
Traditionally, farmers have used slash and burn agriculture to clear land quickly and create some soil fertility for agriculture.

This system worked well in the past with low populations and large areas of forest within which to move for the next crop. However, today most regions have little or no remaining forest, farmers have fixed areas of land, and populations are large and growing. Therefore, the burning happens in the same areas every year. Farmers use fire to save time when removing weeds, but the ash created has no nitrogen, is not a complete fertiliser, and most of it gets blown or washed away. Burning creates a lot of damage and production gets less and less.

Why stop burning?

Burning year after year results in the loss of the soil's organic matter and this, in turn, leads to the loss of soil fertility and structure, and its moisture-holding capacity. Eventually, the degraded soil is much more easily eroded, and on sloping land, is more prone to landslides.

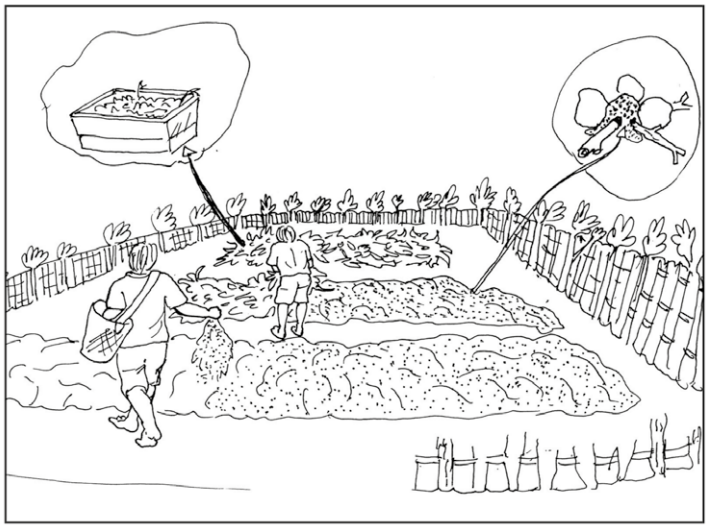
- Burning destroys all the organic matter and soil biota that are necessary to improve and replenish the soil.
- Burning destroys plant material that can be used for mulch on your cropland.
- Wind often removes the ash before it can enter the soil and, on sloping land, a lot of the ash washes away with the first rains and is wasted.



- Fire spreads quickly, especially when there is strong wind, and can damage dry season crops.
- If the land is burnt each year, you cannot plant windbreaks to protect and improve your crops.
- If the land is burnt each year, there are a lot fewer birds and insects to provide natural pest control.
- Burning creates carbon dioxide (CO_2) which contributes to climate change. If farmers across the world stop burning, there would be less carbon pollution to contribute to climate change. Changing our practices now could slow down climate change and reduce some of the negative impacts on the planet.

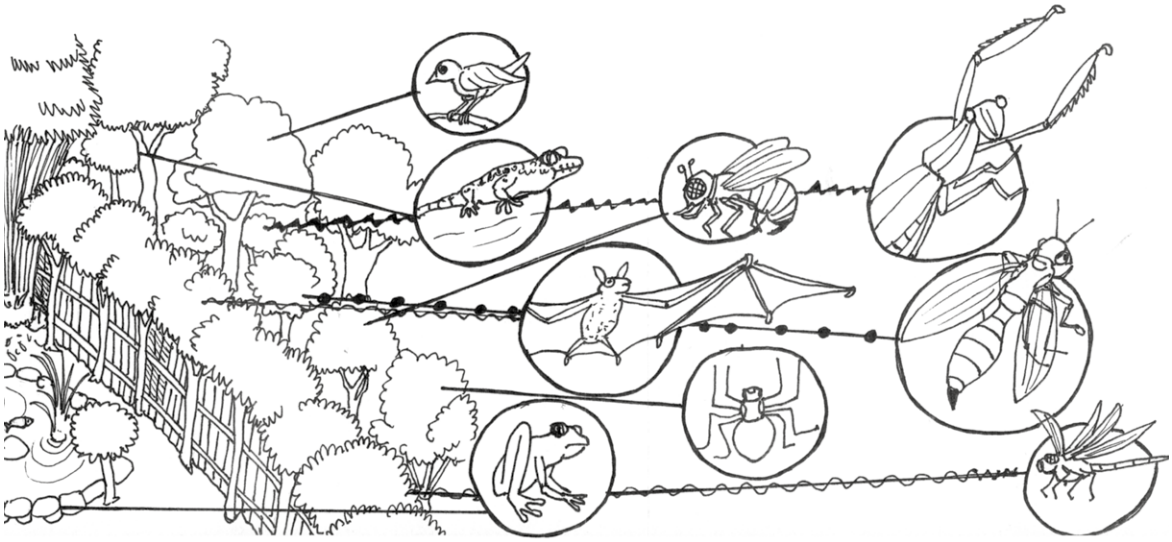
Ash in fertilisers

You can stop burning the land and still get the benefits from ash. Make ash and charcoal from specialised burning of bamboo and wood. Add it to compost and liquid compost, or spread it directly on the soil, and immediately add compost and/or mulch.



8. INCREASING THE NUMBER AND TYPES OF TREES

Planting more and various types of trees around your croplands provides many benefits. Most importantly, trees protect the soil, and reduce erosion and wind problems.



Examples of pest predators that will reduce pest problems if you provide them a healthy environment

They attract birds, spiders and helpful insects, such as bees, wasps, ladybirds and beetles. The birds, spiders and insects help to control pest insects, therefore, reducing problems for crops. They also increase pollination, which increases yields. The trees make a barrier that slows the spread of pest problems.

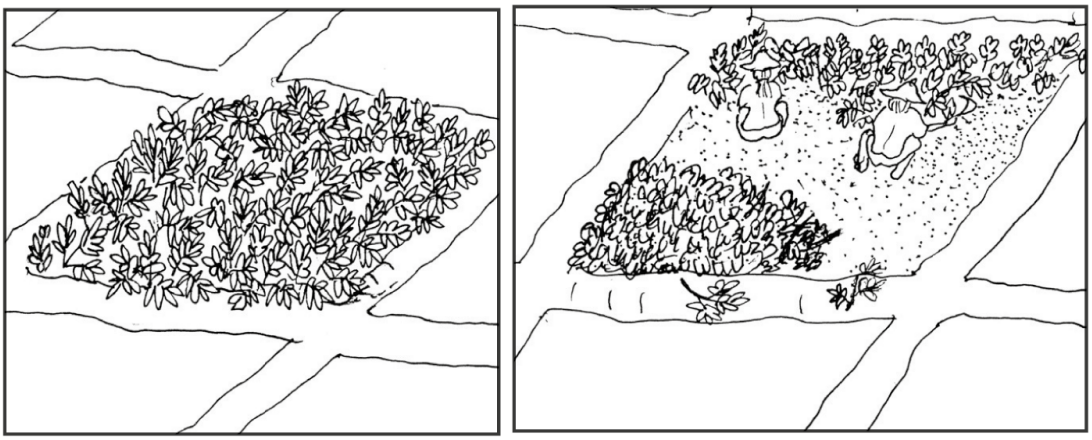
Trees also provide many different products. Remember to think **multifunctional.**

9. IMPROVING VERY POOR SOIL

Sometimes the soil is very poor and needs improving before more crops can be grown. In this situation it is best to take steps to quickly improve the soil, which may take a year or two. If you immediately plant crops on land with poor soil, the yields are very low, and cost money and time.

Strategies include:

- Grow cover crops continuously for a year or two. See cover crops in the natural fertilisers and mulch section in this chapter. Small clumping grasses are good to include here as well because they collect a lot of nutrients.
- Grow green manure crops. These are more intensive and better for smaller areas of land, but still work very well.



Green manure crop in a rice paddy

Soil with long term diseases

If you have bad soil diseases, it means the soil must rest for a while. To remove the diseases, you can use the same strategy of planting cover crops, including small clumping grasses, to improve the soil. Allow cows to graze on the land sometimes, as their manure is good for soil health. Add some bacterial activator to the soil as well, as the good bacteria accelerate the removal of soil diseases.

Land and crop management

How you manage the land and your crops impacts on every crop yield and on future crops. If you use sustainable practices, the positive impacts build up over time and help to provide more consistently good yields and resilience to poor weather.

1. PRE-PLANTING TECHNIQUES

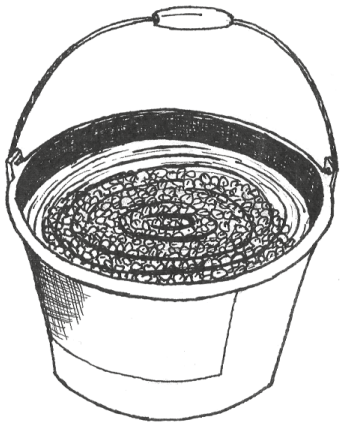
Seed priming – Soak the seeds in water for 18 hours before planting them.

This simple technique improves your germination rate, plant growth and crop yield.

When plants get a good start with healthy growth and minimal stress:

- They grow better throughout their lifecycles.
- They are better able to cope with dry periods and weather extremes.
- They become bigger plants.
- The result is better production.

This is an important climate change mitigation technique.



Seed protection – Use custard apple (*Annona squamosa*) seed and leaf powder for protecting seeds when planting, especially for corn, beans and other big seeds that can be damaged by ants.

Method:

- Crush one cup of dried seeds and half a bucket of fresh leaves, and add them to a 10lt bucket of water.
- Leave the mixture for three days until it ferments.
- Add the seeds for planting and soak them for 18 hours.
- Plant the seeds.

2. NATURAL PEST AND DISEASE MANAGEMENT

Many farmers turn to chemical pesticides and fungicides to provide a quick but expensive solution to crop pests and diseases. The quick solution actually creates bigger problems, especially in reducing soil quality. As pests become resistant to the pesticides, the problems get worse not better.

Natural pest and disease management provides short and long-term solutions, as well as allowing your soil quality and land to improve. There are many different parts to natural pest management. It is best to prevent problems from occurring, and to minimise their impacts. A healthy system with healthy, nutrient-rich soil, and good land and crop management minimises pest and disease problems. There are also many natural organic pesticides and fungicides to use if problems do occur.

The next chapter (**Ch 14**) explains a system called Integrated pest management (I.P.M.), which is a natural method used in many countries to prevent and treat pest and disease problems.

Farmer checking for pests and leaf damage

3. WEED MAINTENANCE

Weeds can negatively affect agricultural production and the environment around agricultural land.

If weeds are not controlled, they compete with the agricultural crops by using the available nutrients and water, and reducing yields. However, if weeds are put back onto the ground as mulch, some nutrients and water are returned, and it greatly reduces future weed growth. If they are burned, the benefits are lost. More weed removal equals better production, more plants and a larger crop size. If possible, remove weeds at least once a month, and always use the weeds as mulch for the crops.

Removing weeds before planting:

- Remove them by hand

Ploughing helps and is better than burning, but it also creates problems as it:

- Damages soil structure
- Kills lots of micro-organisms
- Reduces the amount of water the soil can hold, therefore, increasing irrigation needs
- Causes a lot more weed seeds to germinate

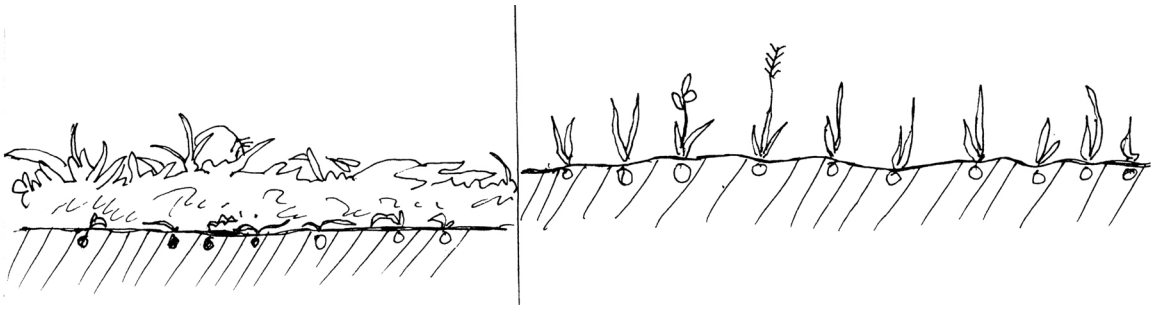
If you must plough, do it once only. Use good techniques and minimise compaction, so you do not need to plough before every crop or every year.

Cover crops are excellent for weed control: e.g. velvet bean, cow pea, sweet potato, pumpkin, pinto peanut, calopo, desmodium, vigna spp, lablab bean, crotalaria and centrosema spp. In the wet season plant the cover crops close together to cover the ground and compete successfully against the weeds. They suppress most weeds and even reduce the problem weeds such as running grasses and nut grass making it easier to remove them. Cover crops also improve the soil, provide mulch and compost material, and add nitrogen if they are legumes.

Cover crops reduce weed problems

Use techniques to reduce the number and types of weeds each year.

- Remove the worst weeds first!
- Mulch is very important to reduce the number of weeds. It covers the ground and many weeds die before they can break through the mulch layer. The thicker the mulch layer, the lower the number of weeds.

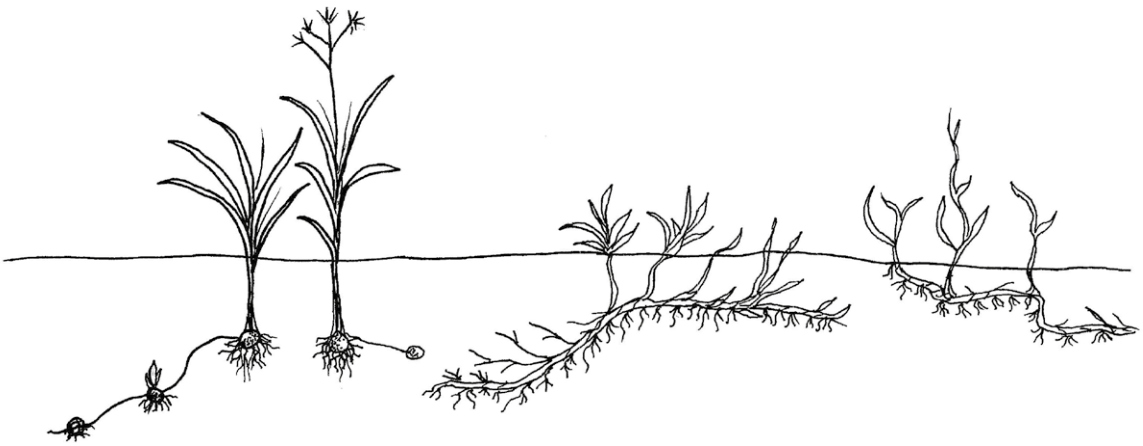


Mulch prevents weed growth

No mulch means the weeds grow easily

- Minimise competition by planting crops with just enough space for each one to grow to full size.
- Plant cover crops to reduce weed growth by blocking the sunlight, essential for seed germination. They also improve the soil and the production of other crops, and provide food: e.g. pumpkin, velvet bean, sword bean.
- Use different techniques to control different weeds. Annual weeds can be slashed but perennial weeds should be pulled out before they become too old and hard to remove.
- Use the weeds as a green manure crop. Make sure you remove the weeds before the weeds form seeds, and each year the number of weeds is reduced.

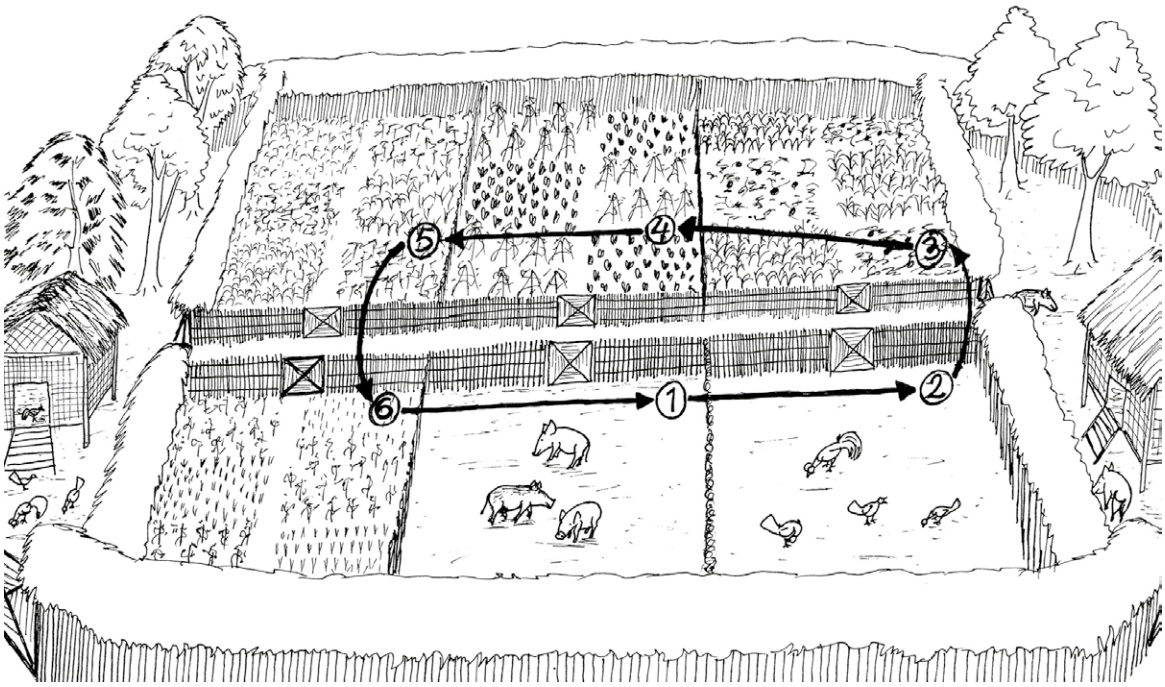
- Observe the weed growth and types. Are new weeds growing? What weed control technique is best for each type of weed? Which weeds reduce crop production the most?



Problem weeds - nut grass, kikuyu and couch grass

- Controlled use of grazing animals removes a lot of weeds before and after crop production. They also provide manure.
- Remove the weeds before they seed. If they do go to seed, remove them and put them in one place. This reduces next year's maintenance.
- For irrigated vegetables crops in the dry season, especially tomatoes, beans, eggplants, etc., more specific irrigation means fewer weed problems. Flood irrigation means many weeds grow over the whole vegetable plot. Specific irrigation for crops means water is only given directly to the vegetables. Fewer weeds grow, maintenance is MUCH easier, and a lot of water is saved.

DANGER: Burning is a quick method for removing weeds but it causes many problems and reduces the soil quality each year. It also encourages weeds to grow that have less nutrient value, are much harder to get rid of and, for each year of burning, this gets worse. There are many better alternatives.



Animals follow crops to remove weeds and weed seeds

Valuable weeds

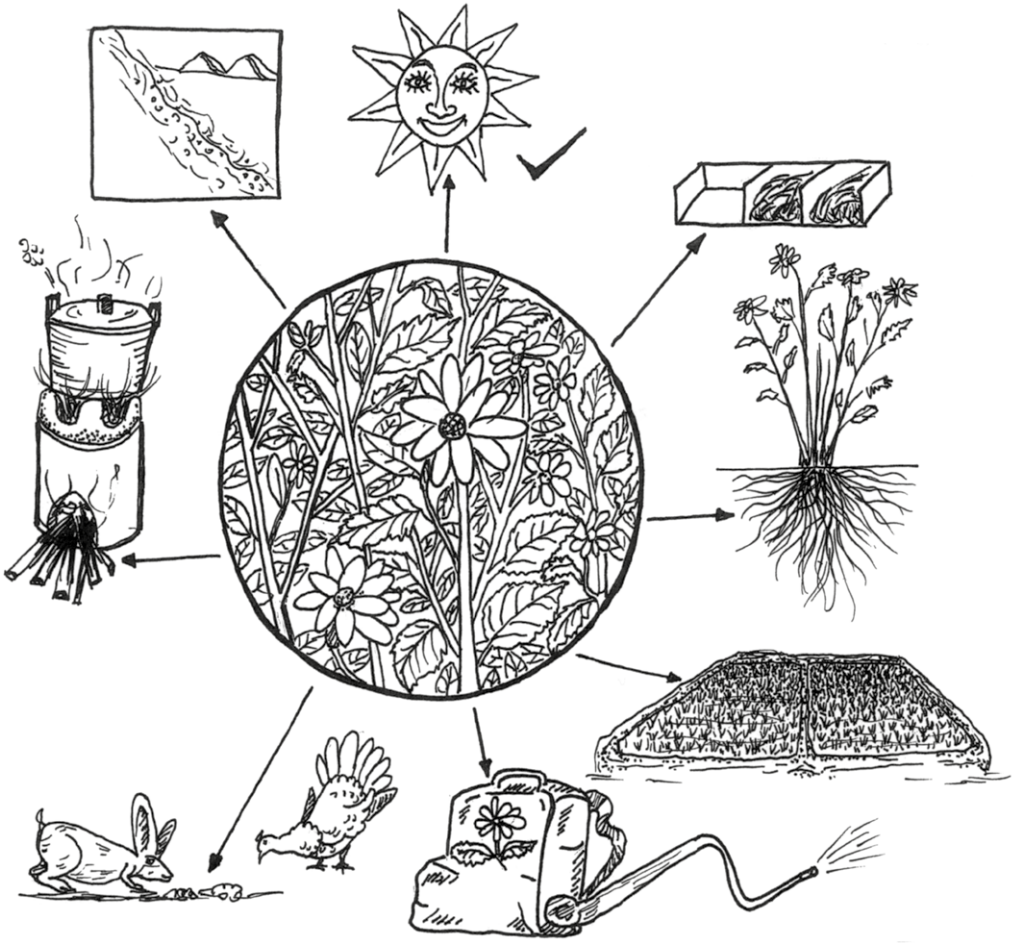
Weeds provide many functions and products. Make the most of them to improve your agricultural production as they are good for:

- Mulch and compost material
- Organic matter
- Protecting the soil from erosion
- Products, such as fibre and paper
- Providing homes for pest predators and attracting pollinators
- Indicating what grows well as many weeds have productive plants for relatives: If a weed grows well, its productive relative probably does too.

Tithonia diversifolia (Tree marigold or Mexican sunflower) is a great example. It is an entrenched weed in most tropical countries. However, it has many uses and should be considered a valuable part of a productive farm!

Some of *Tithonia diversifolia's* uses:

- Biomass producer – large amounts are produced which can be used for mulch, organic matter, compost material and liquid compost material.
- Soil improver – the roots loosen the soil and make it better for other crops.
- Green manure crop – it can be used as a green manure crop for agricultural land and rice paddies. See Soil (**Ch 9**).
- Fertiliser – a fertiliser can be made directly from crushing the leaves and mixing them with water.
- Animal food – it is great food for rabbits, and is good for part of a chicken's diet too.
- Firewood – it is a good fire fuel, especially for clay and other wood-burning stoves and ovens.
- Problem weed prevention – it has been used to out-compete other weeds that cause problems.
- Erosion control – it covers bare soil on sloping land.
- Drought tolerant – it is great for dry tropical regions.



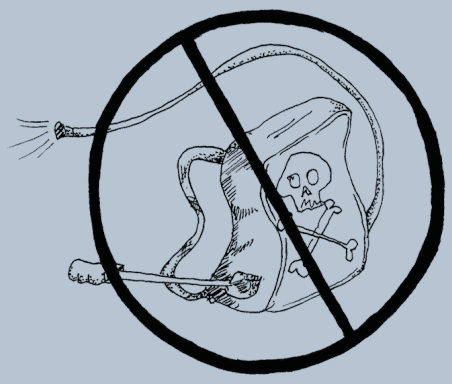
The many uses of Tithonia diversifolia

There are many other land and water weeds – such as purslane, water hyacinth and duck weed – that can be used to fill many needs, turning problems into solutions.

For more weed information read the weed management section in Family gardens (**Ch 10**) on:

- Vinegar, molasses and other herbicides
- Problem weeds: running grasses and bulb weeds
- Weed barriers

DANGER: Chemical herbicides are a quick-fix solution that can cause much more harm than good.



Chemical use causes the loss of a lot of the biomass, animal food, and compost material. Weeds are a valuable resource when you use them properly and are an important part of natural production cycles.

Chemicals damage the soil: algae and fungi in the soil are depleted by chemical herbicides, which disrupt your living soil and, in turn, reduce production rates.

There is a danger of misuse when farmers cannot or do not read the labels properly: overuse leads to herbicide residues in the soil which damage the next crops planted.

Many chemical herbicides are highly toxic and can be dangerous to animals and people.

They often do not remove the problem weeds unless you treat them multiple times and are very expensive for most farmers.

New research shows that some chemical herbicides, which were previously considered safe, actually create problems for bees, soil worms and people.

4. CROP ROTATION

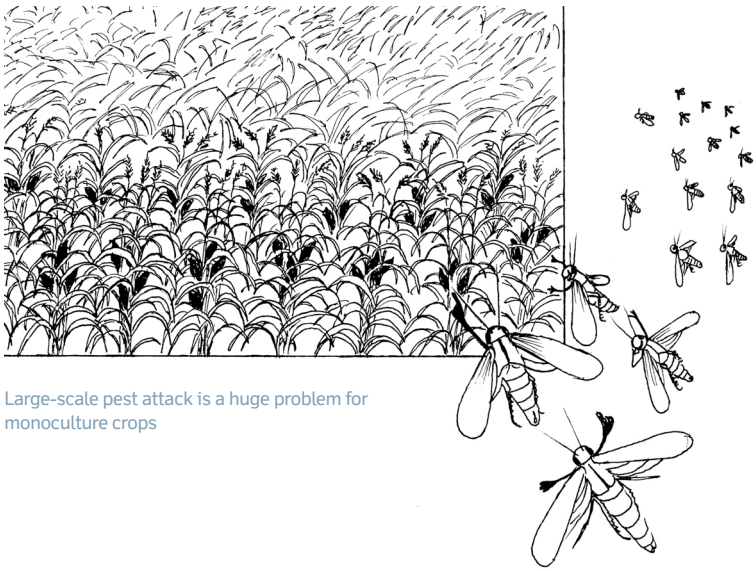
Crop rotation is an important part of sustainable agriculture management as it:

- Balances nutrient use
- Reduces pest and disease problems
- Adds diversity

A simple guide is not to put plants from the same family in the same place two seasons in a row.

Crop rotation cycles can also include green manure crops, which add lots of nutrients and organic matter. This feeds the soil and prepares it for the next crops.

Read the Family gardens chapter (**Ch 10**) for more information.



Large-scale pest attack is a huge problem for monoculture crops

5. INTERCROPPING VEGETABLES, GRAINS AND SMALL TREES

Intercropping means to mix together different types of grains, vegetables and even small trees.

There are many benefits of intercropping and many different combinations.

Combinations

Legume trees, small fruit trees, grains and vegetable crops:

- The legume trees provide shelter, mulch, nitrogen and food, and can even be a living fence and a trellis for beans: e.g. pigeon pea, sesbania, leucaena, albizia, etc.
- Small productive trees can also be grown: e.g. papaya, banana, pineapple, citrus, moringa.
- Trees reduce pest problems.
- The grain and vegetable crops can be grown in between the trees. The different grains and vegetables can also be mixed together, as can the legumes and fruit trees.
- The combinations you choose and the way of combining them is up to you.

Corn and peanut rows

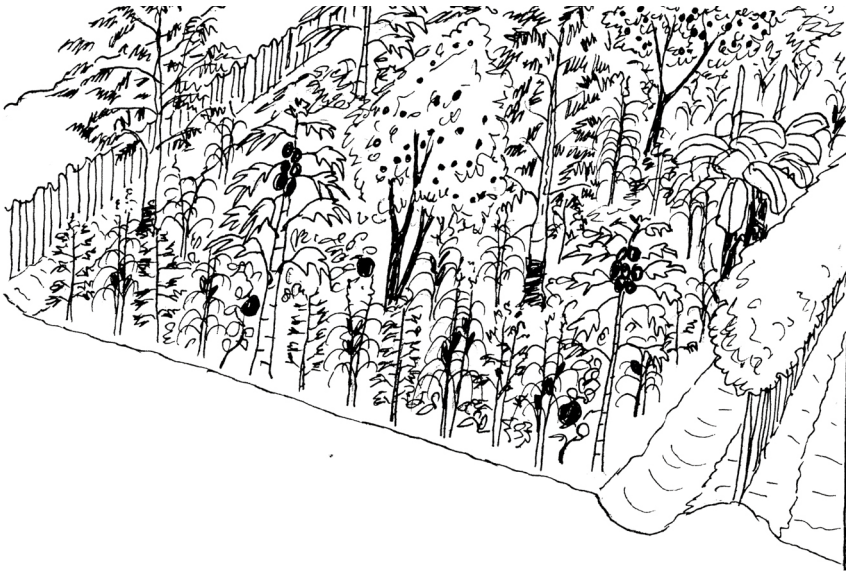
The corn shelters the peanuts and the peanuts provide nitrogen for the corn. Recent trials in Timor-Leste show an improvement in both corn and peanut production from growing them together.

SMART IDEA:

Always combine plants that have similar watering needs. This minimises water use and prevents a reduction in production from too much or not enough water.

Corn, pumpkins and beans

This is a traditional combination in many countries that provides three different crops in the same space.

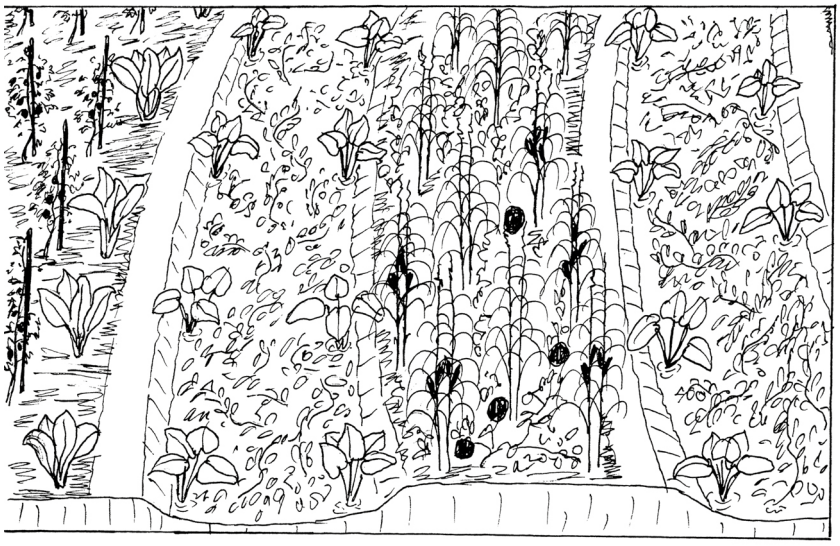


Cassava combinations

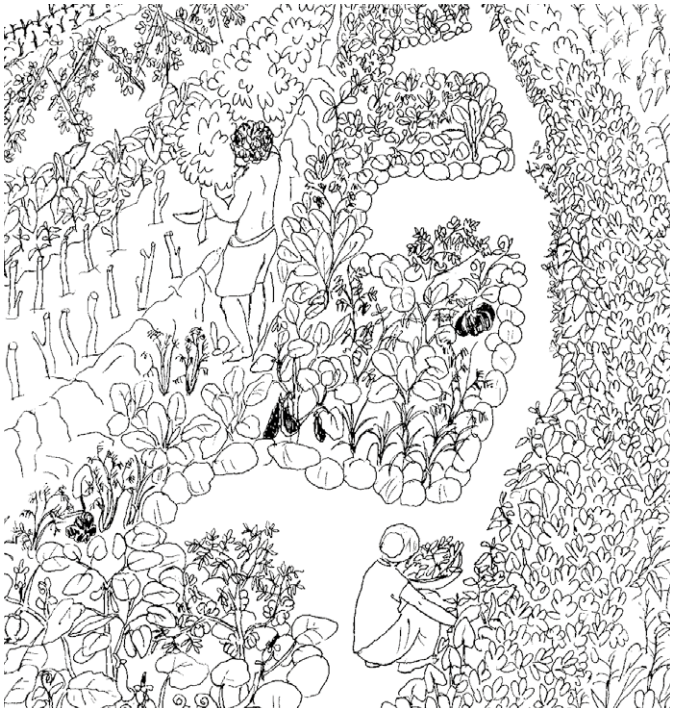
Cassava can be grown with small trees, such as papaya, sesbania, moringa, pineapple, pigeon pea and banana. The cassava benefits from the shade and from the nitrogen produced by the legume trees. Be careful not to grow them too close as the cassava roots can become crooked and smaller if they have to compete for space and become bitter if they are too close to legume trees. Climbing beans can be grown up cassava trunks, plant the beans and cassava in separate rows.

Mound and trench combinations

Mound rows with trenches dug in between are good for holding wet season rain and for irrigation. The mounds can be used for different grains, vegetables and even some legumes and small fruit trees, and in the trenches you can grow water spinach, watercress and taro. They work better if the mounds and trenches follow the contours of the land.



Swale-planting ideas



Planting in the trenches, on the mounds and between the swales

Wet season

Swale trench: Taro, water spinach, watercress and other plants that like a lot of water can be planted at the bottom and sides of the trench. You can put plants that like a lot of water but do not like being submerged along the edges of the trench: e.g. lemon grass.

On the swale mound and between the swales you can grow many vegetables and small trees: e.g. tomatoes, eggplants, pumpkins, cassava, chilies, capsicums, cabbages, green-leafy vegetables, sweet potatoes, papayas, bananas, watermelons, beans, peas, cucumbers, corn, lettuces, pineapples, pigeon peas, peanuts, and many more.

Dry season

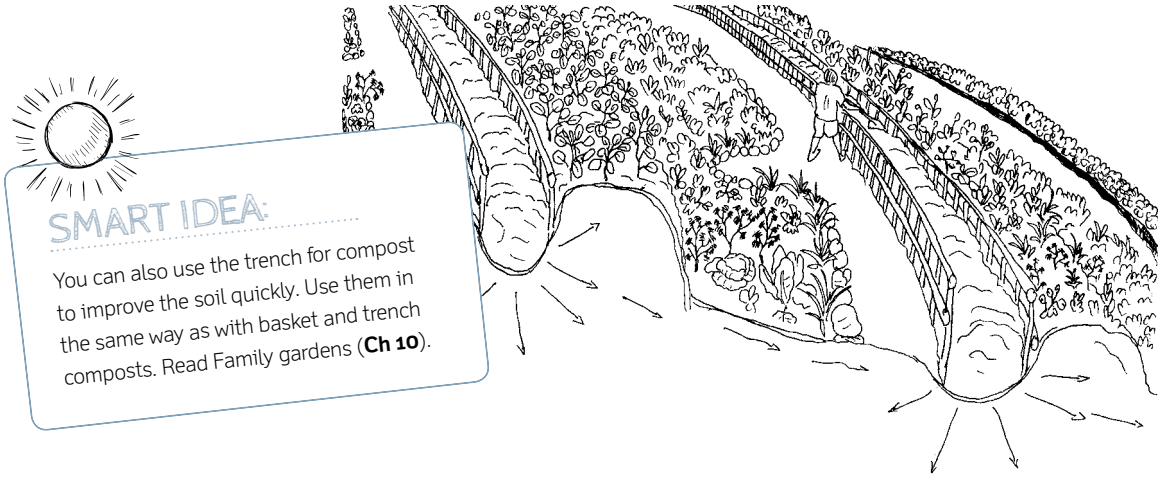
If a good water supply is available, continue with the wet season ideas.

If only a small amount of water is available, the trenches can be used for vegetables and, on top and between the swales, you can continue to grow long-term plants, such as cassava, pineapples, eggplants, bananas, and so on. Alternatively, the area can be mulched and left for the next wet season.

If no water is available, some long-term drought tolerant crops can still grow, and do a lot better with than without swales. Mulch the land and wait for the next wet season. The growing season for these vegetables increases because the water in the soil lasts longer, especially in areas that have little or no water.

In the mountains, where dry season rainfall is more common than on the coast, swales create good conditions for growing vegetables and other plants all year round. Over time small animals can also be integrated into the system. Remember to use soil improvement techniques to get the most benefit from the swale gardens.

The Trees chapter (**Ch 15**) has many ideas for combining agricultural production, tree crops and animals using swale systems.



SMART IDEA:

You can also use the trench for compost to improve the soil quickly. Use them in the same way as with basket and trench composts. Read Family gardens (**Ch 10**).

6. REDUCING SOIL COMPACTION

Soil compaction causes many problems for sustainable agriculture:

- The soil holds a lot less water.
- The amount of soil biota necessary for healthy soil is much lower.
- The soil contains a lot less air.
- Plant roots find it much harder to grow. They are smaller and grow close to the surface, which means they suffer more in variable climate conditions.

Compacted soil

All these problems cause smaller crops, higher water use and increased erosion.

To reduce soil compaction:

- Poor soil becomes compact as it dries. Healthy soil with organic matter and mulch dries a lot slower and is less compact when dry. Use tree terraces, swales, rock terraces, etc. to build up the soil.
- Use raised garden beds.
- Buffalo ploughs cause a lot less compaction than tractors.
- Do not graze too many heavy animals (buffalo, cows) on your cropland between planting crops.

Even people cause compaction. Use just a few paths for walking so only the paths are compacted. This is very important on sloping land.

Non-compacted soil

7. PLANTING TIMES IN THE WET SEASON

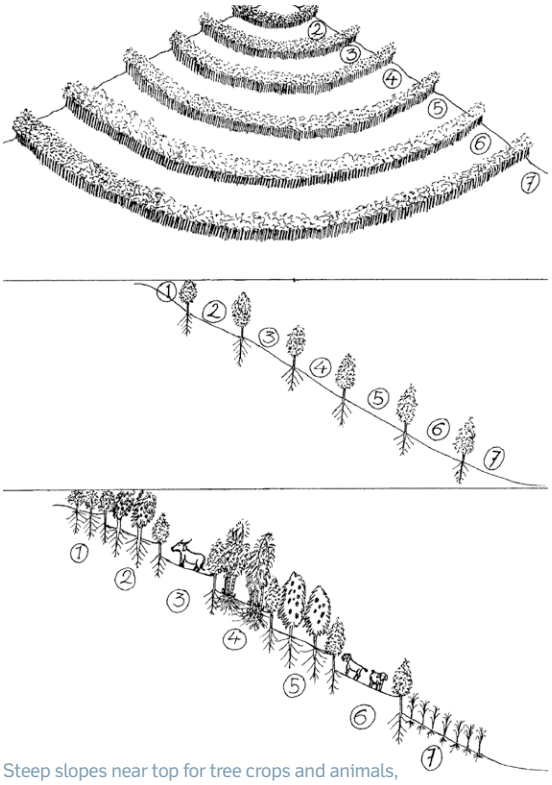
Crops are often planted after the first or second good rain. This can sometimes lead to crop failure or a smaller crop size if there is a period of time before continuous rain starts. The best time to plant a crop is to wait until the third or fourth good rain or until it starts raining every day. This gives a much better chance of a successful crop. However, the first one or two months of the wet season are often times of food shortage. Planting a small crop after the second rain, and then a bigger crop after third or fourth rain, can relieve food shortages and give better crop security.

8. PUTTING LAND TO ITS BEST USE

Sometimes people plant crops on land that is too steep.

This leads to erosion, is not sustainable and is very hard work. Some solutions are:

- Use tree terraces to hold the soil so your crops can grow without causing erosion. Plant trees to hold the soil in place and stop landslides. These trees may be legumes to be later cut for animal food and mulch.
- Grow tree crops. Small swales help the trees to grow and they hold the soil. After a few years when the trees are tall, you can raise animals on the land as well.
- Use the land for raising animals, preferably goats or poultry. Plant legumes and other trees for animal food and shade. Animal production (animal husbandry) can earn you more money on steep land than other forms of agriculture.



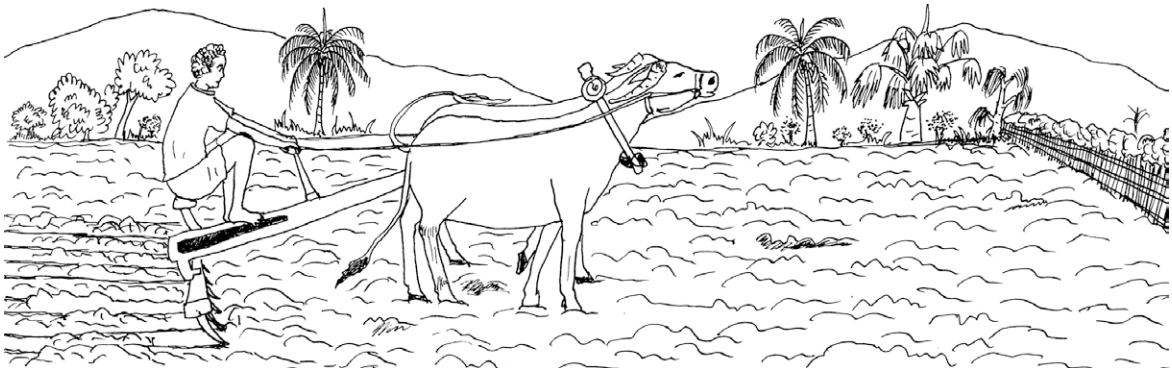
Steep slopes near top for tree crops and animals, gentle slopes near bottom for annual crops

9. USING BUFFALO/COWS TO PREPARE LAND

The process of ploughing the soil originally came from temperate climates and is not as appropriate for tropical soil and agriculture.

When tropical soil is turned and exposed to rain and sun, it loses nutrients and micro-organisms very quickly. If you do plough, be very careful to make sure the soil is covered with mulch as quickly as possible, and it is protected from erosion in the wet season.

Buffalo and cows can be used to prepare croplands and rice paddies for planting. This improves production and reduces preparation time. They can also be used for ploughing contour lines on slopes and helping to prepare sloping land for planting trees.



Soil quality – Good soil structure is very important for healthy soil and, in turn, for healthy crops. It is better to plough a line through the soil to make it easier for the plants to grow, and it does not damage the soil structure. Buffalo ploughs work in this way. Turning over the soil damages the soil structure.

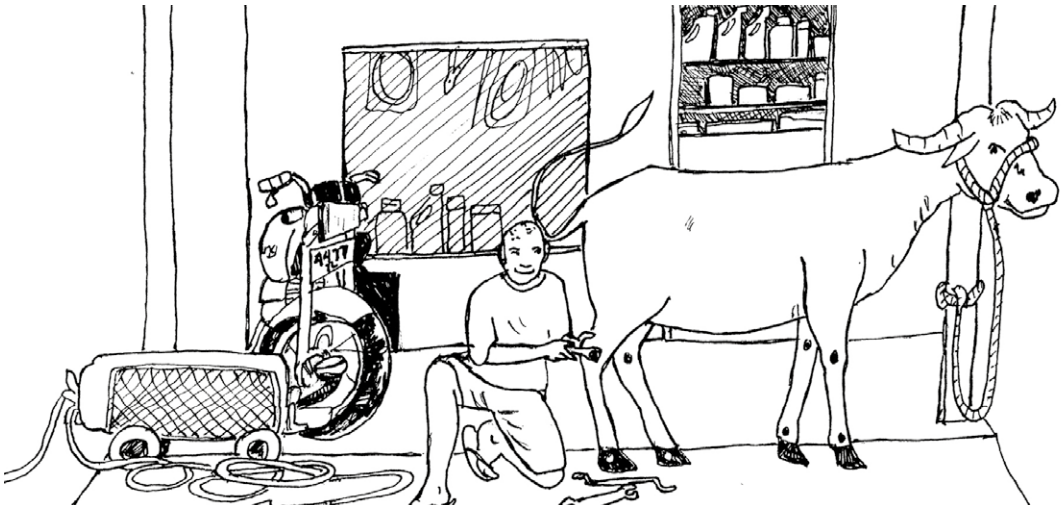
Cost – Buffalo are not cheap, but, if well cared for, they are able to work for many years. Once a family, farmers or community group has a male and a female buffalo, their buffalo numbers slowly grow.

Care – Buffalo need to be healthy to be able to work well. They need food, water and shelter, and medical care when they are ill or injured. Caring for buffalo requires time but not a lot of money. Grow animal fodder trees to help provide better food for your buffalo all year round.

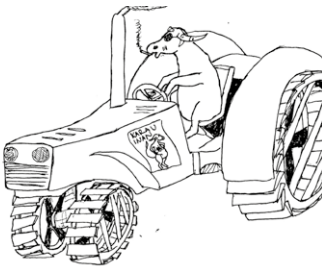
Training – In some countries buffalo have not been regularly used for ploughing, but there are many groups now giving training. Almost anyone can learn how to train buffalo and how to use buffalo ploughs. Read the buffalo section in the Animals chapter (**Ch 17**) for ideas about training and using buffalo.

Lack of flat land and road access – Buffalo can be used on slopes as well as on flat lands, and can be kept anywhere, as long as they have water and food.

Other benefits from buffalo – Buffalo also provide milk, meat, leather, manure and more buffalo, and you can make an income from selling any of these buffalo products.



About tractors



Tractors take a lot less time to prepare land for planting and can be good for large flat areas. However, there are many other factors that must be looked at when deciding if a tractor is beneficial or not.

Soil quality – Most tractor ploughs turn the soil over. This helps crops to grow but damages the soil structure and biota. Therefore, the soil quality gets worse not better over time, and this reduces production. Tractor ploughs that cut through the soil rather than turn it over are much better.

Cost – Tractors cost a lot of money to buy, which is too much for most people, even farmers groups. It is much better to rent a tractor, but that is still expensive. How long you need it for depends on the size of the tractor and the amount of land.

Maintenance – Tractors cost a lot of money to maintain every year. Petrol, oil, tyres, engine and hydraulic maintenance are only the start. Tractors also need people who have a lot of specific knowledge to maintain them. Spare parts can be very hard to find and sometimes need to be imported from overseas. Tractors also need somewhere to store them t o keep them out of the rain.

Training – Tractors are much harder than cars to drive and require a lot of training.

Lack of flat land and road access – Tractors are very hard to use on sloping land. Access is also a problem where the roads are too narrow or become blocked in the wet season. Many farming areas have no road access.

Hand tractors are used in most tropical countries: they are much more versatile than ride-on tractors, especially for sloping land. However, as with big tractors, the type of plough a hand tractor uses is important. Ploughs that turn the soil over still cause damage. Ploughs that cut through the soil without turning it over are much better and can be part of a sustainable land management system.

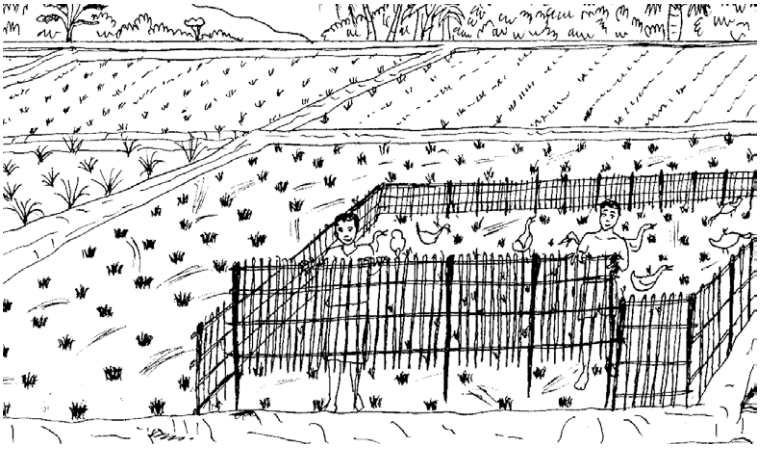
10. INTEGRATING WITH OTHER SYSTEMS

Different systems work better if they are integrated into one system. Maintenance is cheaper and easier because the waste from one part can be used as a resource for another part of the system.

Overall production from the land increases.

Rice paddies with ducks

Ducks love to clean up after a rice harvest. They can be rotated from one paddy to another using a moveable fence and rotated for short or long periods in each paddy. This depends on how many ducks, how many paddies and how many crops there are per year. The ducks fertilise the paddies and prepare them for the next crop.



Using ducks after rice harvest

Trees and annual crops

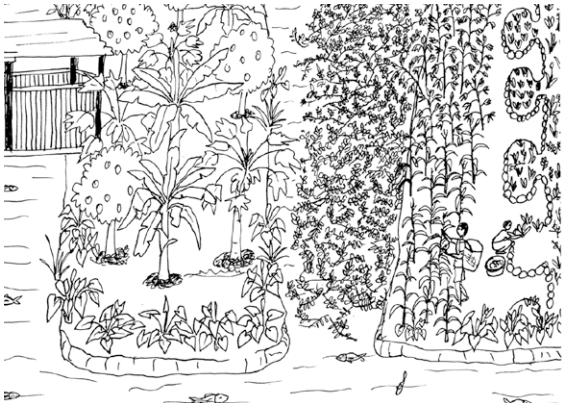
Small fruit and legume trees grow well with grains and vegetables. The trees can be harvested and help to increase the production of grains and vegetables. They can be grown in rows, around the cropland or in groups. Read the Trees chapter (**Ch 15**) and earlier in this chapter for further explanation and many different examples.

Animal grazing and crop production: rows and plot rotation

Animals can be grazed on the cropland after harvesting, and fertilise the soil. Be careful not to leave buffalo and cows in one spot for too long or the soil becomes compacted. Legume trees grown in rows, or dividing cropland into sections, provide living fences for animal grazing and for fodder.

Rice paddies with fish

With careful management fish can be raised in paddy systems at certain times of the year. The fish provide manure for the rice plants. Look in the Aquaculture chapter (**Ch 18**) for more ideas.



Aquaculture run-off

Water from aquaculture ponds is rich in nutrients and should not be wasted. Swales, terraces and paddies can be used to catch and store the run-off water to grow vegetables and trees.

Water trench systems

For areas with a lot of water and soil that holds water, water trenches are highly productive traditional systems that combine sustainable agriculture with aquaculture. Read Aquaculture (**Ch 18**) for more information.

System of rice intensification (SRI)

SRI is a method for increasing rice production. It has been tried in a lot of countries with very successful results. In many places the size of rice yields has doubled!

SRI increases production while:

- Using much less water
- Using much less seed
- Improving sustainability and protecting the environment
- Using fewer or no external inputs

These benefits mean that SRI will become more and more important as a production technique. It is much more resilient and able to provide good results with fewer resources in hard conditions. This is vital for stability, especially with the increasing impacts of climate change. SRI is a system which works aerobically (with oxygen), where as paddies full of water work anaerobically (without oxygen). Anaerobic rice production produces a lot of CO_2 and SRI doesn't, therefore SRI removes CO_2 emissions from rice production , removing a climate change cause.

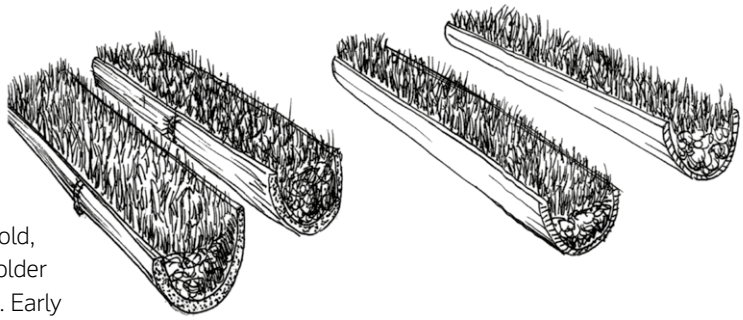
SRI works well on small or large farms. All farmers and communities can use it because the methods do not need new machinery, new tools or special fertilisers and pesticides. It has been shown to work well with traditional and non-traditional varieties of rice. It is especially important for tropical countries with irregular wet seasons and very little or no rain in the dry season. As SRI needs only small amounts of water, it can be used in many places where the flooded rice paddy technique cannot be used. It may also extend the growing season. Using SRI allows more water to be available for other crops. Testing is now underway, using the SRI process for growing crops other than rice.

SRI works best when it is combined with organic techniques, such as compost, liquid compost, bacterial activators and Integrated Pest Management (IPM).

However, the method of irrigation is different and good water control is necessary. Irrigation improvement may be needed, as are training and practice in the new techniques. This leads to an initial increase in the amount of time and labour required. However, when farmers become skilled, the labour time decreases and, eventually, becomes similar to the amount of time needed for usual rice production methods.

SRI TECHNIQUES

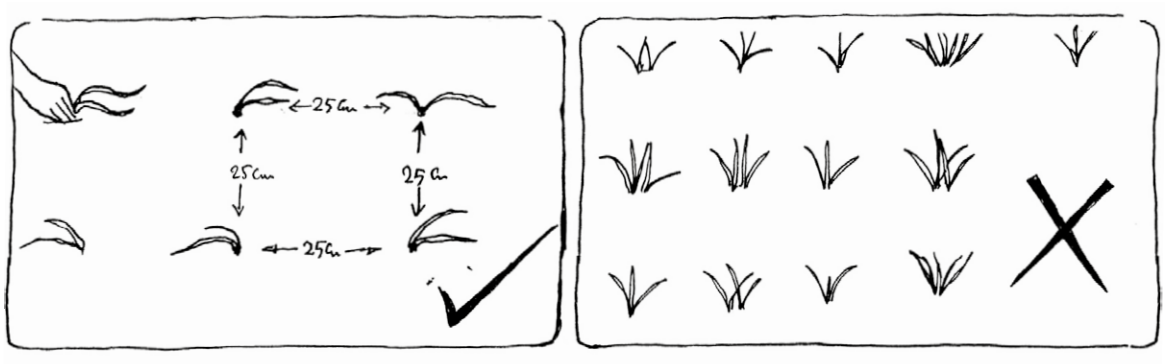
1. Early transplanting



Plant the seedlings when they have just two small leaves and the seed sac is still attached. This is usually when the seedlings are between 8 to 12 days old, but it can vary from place to place. In colder areas this may be later, at 10 to 15 days. Early transplanting gives rice the maximum time for root, leaf and tiller growth. Every day that planting is delayed reduces the growth potential, especially after 15 days. From trials in Timor-Leste, when the seeds are soaked in a bacterial activator over night before planting, the seedling growth is much faster, and they can be planted out even earlier.

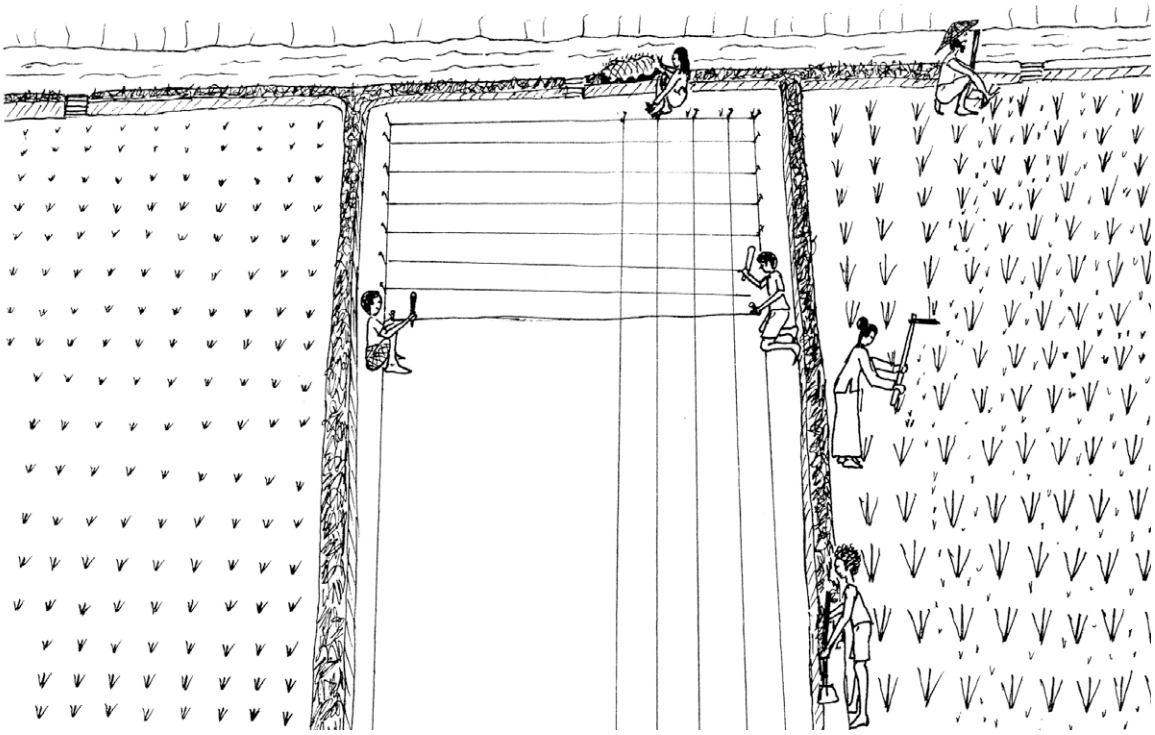
2. Careful transplanting

Lay the seedlings in muddy soil – **do not** stand them in water – with the roots 1–2cm deep and the root tips pointing across or down. If the seedling is pushed into the soil, the root tips point upwards. If the root tips point upwards, growth is slowed or stopped for up to a week while the plant recovers. Careful transplanting reduces root loss and stress on the plant, and reduces delays in plant growth after transplanting. This has a big effect on how big the plant can grow later on.



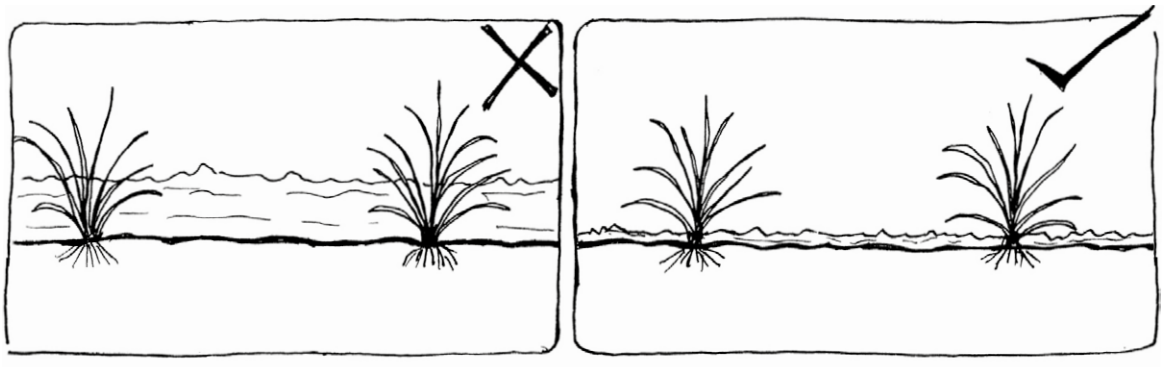
3. Wide spacing

Plant the seedlings one at a time, not two, three or four together. Seedlings are planted in a square pattern, not in lines. Plant the seedlings in squares of 25cm x 25cm. As soil quality improves, the square size can be increased up to 50cm x 50cm for the highest yields. Spacing can be marked out with rope or string, but a better method is to use a special rake to mark out the squares. Wide spacing promotes better root and leaf growth.



4. Well-drained soil

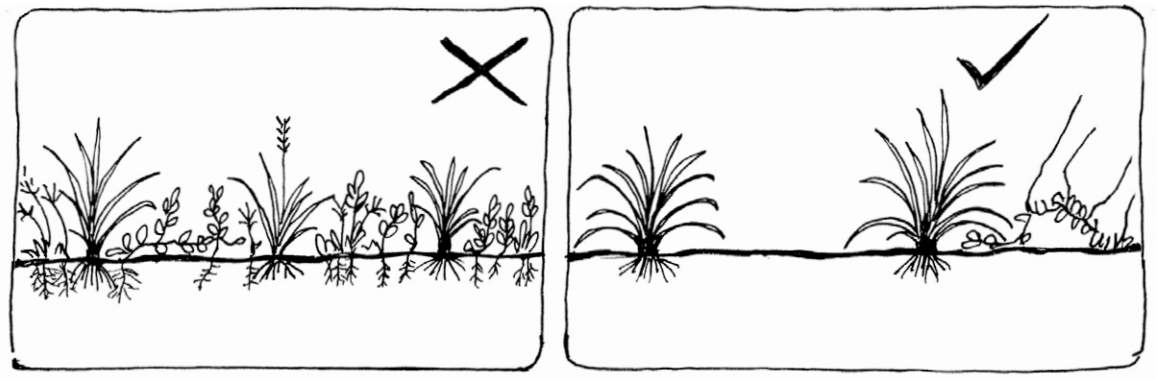
While the plant is growing leaves, only give it enough water to keep the soil moist. Do not allow continuously standing water. When the development of flowers and grains starts maintain a thin layer (1–2cm) of water in each paddy. Drain the water before harvesting, as is usually done. Well-drained soil promotes a much larger root system.



5. Early and frequent weeding

Start weeding ten to twelve days after the seedlings are transplanted. Use a digging bar or hoe. Weed every ten to twelve days until the rice plants grow large enough to shade all the ground (form a canopy).

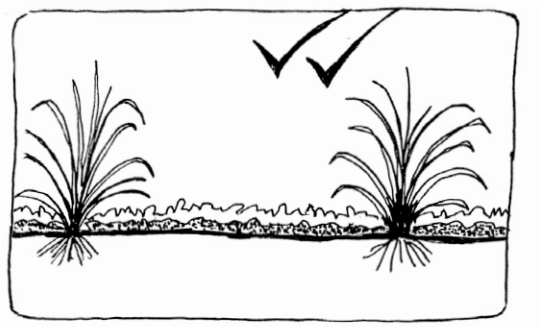
Experiments show that each weeding session adds to the yield of rice by up to a tonne per hectare! Use mulch as weed control as it helps to prevent weeds from growing. Early frequent weeding adds air to the soil, improves root growth and removes weed competition.



6. Apply compost and mulch

SRI works without compost or fertiliser, but compost boosts growth, improves the soil and increases yields. Experiments show that compost and organic fertiliser usually give better results than chemical fertiliser, especially over many years.

Compost and mulch improve soil quality and microbe activity in the soil, which increases nutrient availability and uptake. Mulch is also very important for providing nutrients and increasing soil biota (bacteria, fungus, micro-organisms). The use of bacterial activators helps as well. Read Soil (**Ch 9**).



The reasons these techniques work are because the rice plants have:

- Greater root growth, which leads to more leaves and tillers
- Greater leaf growth, which leads to even more root growth
- Greater leaf and tiller growth and greater root growth lead to larger grains

USING SRI

Farmers and groups interested in SRI need to have training in the techniques, so they have the knowledge and skills to practice SRI. The training can be combined with small experiments on one or two rice paddies to test the results and compare them to usual techniques.

One of the main problems with using SRI is controlling the irrigation water. Flood irrigation and irrigation from one paddy to the next do not give good water control. Therefore, irrigation channels and water gates are needed, as well as training about irrigation control.

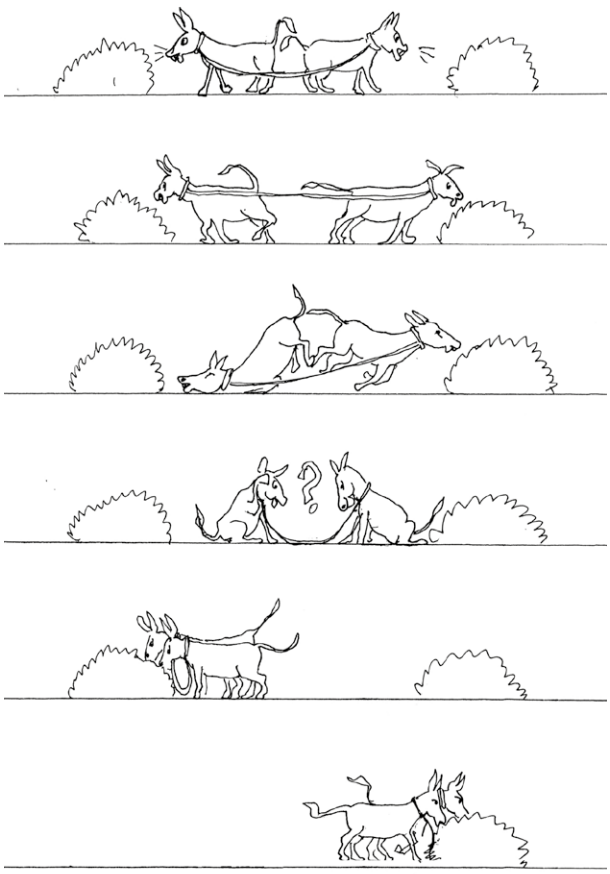
Some solutions for this problem are:

- Start by changing the irrigation for one or two paddies and slowly change the whole irrigation system as time and money allows. The extra yields can provide the money needed to improve the irrigation.
- Community and farmers groups can work with the government, NGOs, agricultural schools or microfinance groups (even better is a combination of these) to arrange training and to improve the irrigation system.

The results of SRI trials in many countries in Asia, Africa and Latin America have shown that SRI should be widely used, especially with climate change making rainfall more unpredictable.

Many NGOs have information on SRI, and there are internet sites to search as well. Look in the **Volume 3 Reference chapter** for information.

Working together



Sustainable agriculture depends on and affects the land around it. Therefore, it is important for people and communities to work together to improve cropland and production. Often many different farms need to share resources, such as water, harvesting and processing equipment, transport, tools and labour.

There are many different levels of working together:

- Family
- Neighbours and community
- Sub-regional
- Regional
- National
- International

All levels are important and different problems require solutions at different and often many levels.

1. COMMUNITY CONSULTATION

Wherever you live there are people with knowledge about sustainable agriculture.

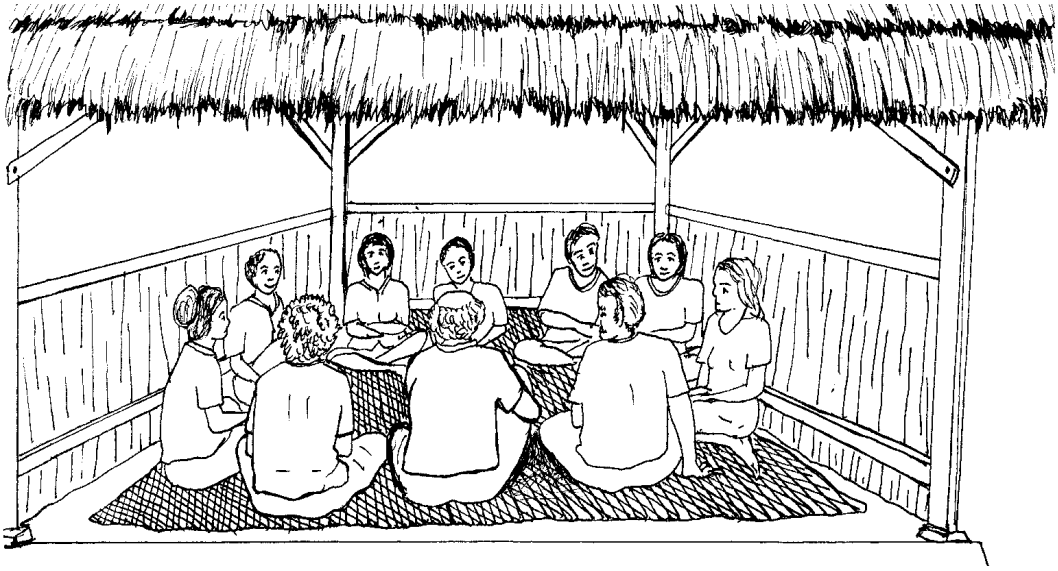
Sharing and gathering information helps to improve agricultural crops. All the men and women who participate in agricultural production must be a part of this process because the best knowledge comes from experience.

Women, who do a lot of crop planting, weeding and harvesting, especially rice, need to be included more in the planning process to make use of their knowledge and observations.

This includes sharing information about:

- What is the best age and time to plant seedlings?
- Which insects are attacking the crops?
- Are there predators that are eating the pests?
- Are there areas where the crops are doing better than other areas? Why? Is it the result of different soil, competing trees, different amounts of water or sun, etc.?

All this information leads to better management and better crops.



2. COMMUNITY PARTICIPATION AND UNDERSTANDING

If many people in a community understand and participate in agricultural development, the development is more productive and more sustainable.

If people work together in communities, whole communities benefit. The range of food and products that people can sell, buy and trade increases. In particular, children benefit because the community has a stronger base for their future.

Issues that require community understanding and participation include:

- Water management
- Burning
- Crop maintenance
- Harvest and marketing
- Use of chemicals
- Waste management
- Fences
- Storage

Example: Water management

Issues to consider:

- If the water source is a river or spring, the land above it affects it, and it affects the land below.
- How do you protect the water source?
- Where does the water come from for the water source, and how is this supply ensured?
- How do you collect the water: e.g. river, spring, well, or pump?
- How do you distribute the water: e.g. pipes, channels, or bamboo?
- How do you share the water evenly between users?
- Who pays?
- What happens if water is wasted?
- How is the irrigation maintained and repaired?

If farmers and the community address these issues together, it is possible to find solutions beneficial to, and understood by the whole community.

As a result:

- Guidelines for water use can be applied.
- Costs are reduced.
- Management and maintenance are easier.
- All factors in supply and distribution are considered.
- The environment and water quality are improved.
- The supply of water is more secure, and can even improve over time with good management.

Teaching children about pest control

Top: Community water supply not well maintained.

Bottom: Community water supply well maintained and safely reusing all waste water

3. COMMUNITY CEREMONIES

Community ceremonies are an essential part of a strong culture, and can improve crop production too. Some examples are:

- Harvesting and planting ceremonies
- Traditional community law ceremonies protecting the environment and farm land. For example: a community agreement on animal management, including how to prevent damage from animals and the penalties for destroying crops. The *Tara Bandu* ceremony from Timor Leste is an example, read Trees (**Ch 15**).
- Ritual pest control ceremonies

4. WORKING WITH GOVERNMENT

There are many ways working with the government improves sustainable agriculture, communities and incomes.

People, community and farmer groups can influence policy and encourage sustainable agriculture at the national level. This includes arranging experiments and demonstrations to show the benefits of sustainable agricultural techniques.

Governments can work with communities to:

- Keep areas with rich soil only for agriculture and do not allow housing or factory developments to ruin them. Rapid development is happening across the world as populations rise; it greatly reduces the amount of highly productive land just as more food production is needed.
- Support the creation of tool, seed and plant banks for farming groups.
- Increase public access to information about sustainable agriculture by providing books and internet sites.
- Introduce field trials for new regenerative and sustainable techniques and technologies.
- Improve storage and transport for produce.
- Promote small business and cooperative opportunities to create and sell local products.
- Improve access to markets.

5. COMMUNITY COOPERATIVES AND FARMERS GROUPS

Cooperatives and farmers groups are the best way to put ideas into practice: resources can be bought more cheaply; harvesting, storage and marketing are easier and more efficient; sharing and trading knowledge, labour, seed, tools and products are easier to achieve at regional, national and even international levels.

Farmer groups can conduct experiments and demonstrations to show different techniques. This allows farmers the option of using them once they have seen the benefits and how to do it.

Importantly, cooperatives and farmers groups are a way to ensure that resources are owned by the people in the community. And remember, governments and large organisations are much more likely to listen to a group than to an individual.

Read Cooperatives (**Ch 5**) about setting up and managing a community group. It is also good to read about ideas for increasing the value of your produce.

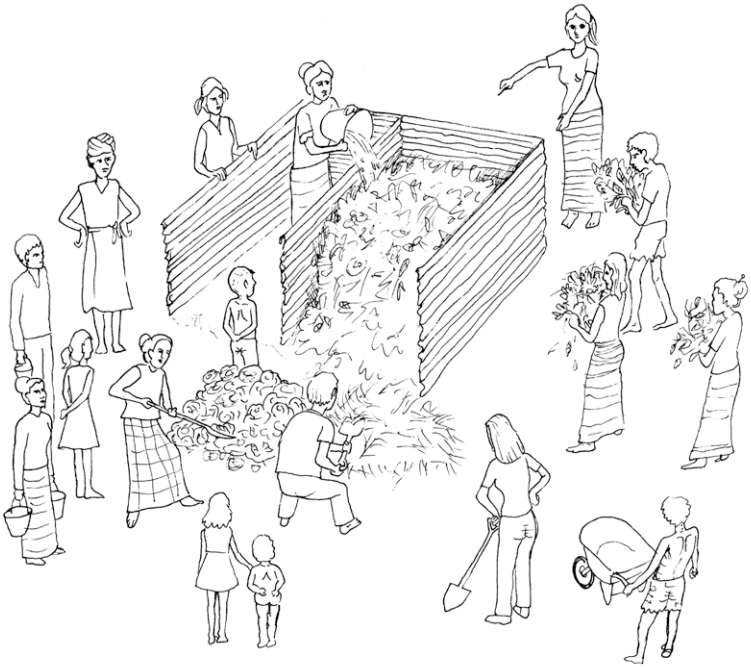
Community farmer's group markets and tool exchange day

Shared labour cooperatives

Sharing labour is a simple but very effective way of making land management easier, especially during busy times, such as land preparation and harvest. Groups of farmers or families, each with their own land, work together on the other's land.

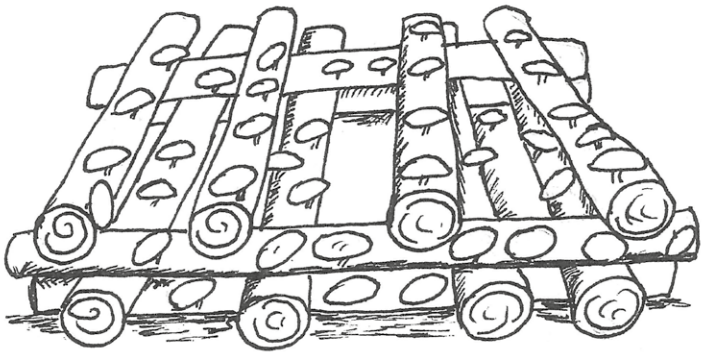
This means that:

- The jobs get done faster.
- Bigger and heavier jobs are easier and less tiring for the workers.
- Experience and knowledge are more easily shared and developed.
- Work time is more communal and often more fun with talking and singing whilst working!



Mushrooms

Mushrooms are the 'fruit' from some types of fungus. They are excellent to have in your garden or to grow for market as a great source of protein and vitamins, especially vitamin B, and are very tasty!



Shiitake mushrooms growing on wood

There are two main ways to produce mushrooms.

Intensive mushroom cultivation

Mushrooms can be grown in a controlled environment specifically designed for producing mushrooms.

This method requires money, infrastructure and daily work, as well as research and training. Once it is set up it does not cost much to manage. It produces mushrooms and a regular income if it is successful. There are other benefits including the production of high quality, ready-to-use compost for gardens and agriculture.

Intensive mushroom cultivation can be organic, which is cheaper and much better for long-term management and for re-using the compost. It requires a separated growing room where other fungus and bacteria cannot enter and where you can regulate moisture, temperature, oxygen and carbon dioxide levels.

In the mushroom cultivation process you:

- **Create the compost** for growing the mushrooms.
- **Prepare the compost for the mushroom spores** – like microscopic 'seeds' – by removing ammonia (from nitrogen) and sterilising the compost so it is free of harmful micro-organisms.
- **Add the mushroom spores.** Thread-like mushroom 'roots' (mycelia) grow from the spores and spread through the compost.
- **Cover the compost.** Add a top layer or 'casing', either old and used compost from previous mushroom crops or a clay-based soil. This provides the place for the fungus to set and grow the 'fruiting body' or the actual mushrooms.
- **Add extra oxygen** into the room to encourage the development of the mushrooms, and make sure the surface of the compost is always moist.
- **The mushrooms grow in cycles:** there is huge growth for a few days followed by a few days' rest, then another growth spurt. This is repeated for over a month, and with some types of mushrooms, it lasts for much longer.
- **After harvesting**, there is a final sterilisation of the room and equipment with steam in preparation for the next crop.

The whole process takes approximately four months. This is only a brief description, so look in the **Volume 3 Reference chapter** for where to find more information and ask your local agricultural department.

Intensive mushroom cultivation is a great opportunity for a small business or for a cooperative. Read Cooperatives (**Ch 5**).

Integrated mushroom production

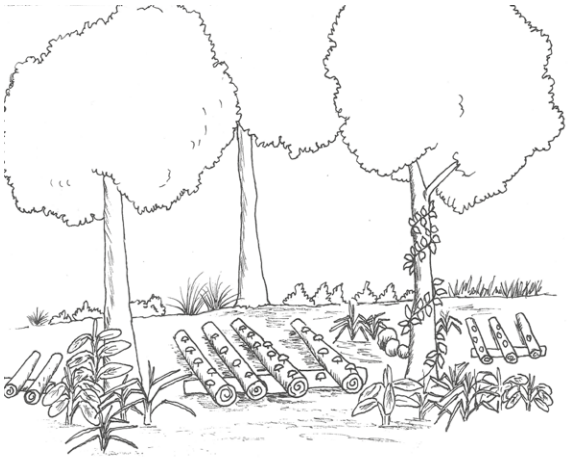
Mushrooms can be introduced and encouraged to grow as a part of your farming systems.

They grow naturally on animal grazing land, in integrated orchards and on agro-forestry land. The mushrooms grow seasonally and in good quantities if they are well managed.
They also help other elements to produce more and are an important part of an integrated, sustainable system.

Mushrooms play an important role in soil and plant health and provide other functions too. Many mushrooms have a natural relationship with plant roots: they feed on sugars and, in return, help plants to obtain water, nutrients and minerals from further away in the soil. Some mushrooms are so small they live inside plant roots! They help plants to grow better, especially in extreme conditions.

Mushrooms can also help in sustainable agriculture and animal systems to improve production:

- Oyster mushrooms have been shown to eat some types of nematodes (microscopic worms that live in the soil and damage plant roots).
- Pigs love mushrooms! Feed them any edible mushrooms which are not good enough quality for selling or eating.



MUSHROOM TYPES TO GROW

It is good to identify and grow local edible mushrooms because these fungi already grow well in your region. Make sure all the mushrooms you grow are known to be edible and do not cause any sickness!

Introduce the mushroom spores and 'base' into the garden. The base is the part of the fungus that lives in the ground from which the mushrooms grow. The best method is to take some soil and/or plant material from where the mushrooms have been growing. Add this directly to your garden beds or to a mushroom-growing space. Look at the type of material the mushrooms grow from and add this or something similar to the garden beds/growing space as well.

Many countries have mushroom-growing businesses; you can use their old soil which contains the mushroom spores and fungus base.

Common mushrooms tend to grow on and decompose wood, vegetation and manure but they do the same on dead insects and animals too. Vegetation from which to grow mushrooms includes different types of wood (branches and saw dust), rice husks, rice straw, corn stalks and sugar cane straw (remains from processing). Some mushrooms even grow on used coffee grounds.

Harvesting mushrooms from a vegetable garden

MUSHROOM MAINTENANCE

It is very important to copy the mushrooms' natural growing conditions. This varies with different mushroom types and includes:

- The right amount of shade
- Soil PH – if the mushrooms like acidic soil, you need to prepare a separate growing area for them.
- The right amount of moisture
- The right temperature
- Soil type – sandy, clay or mixed
- Canopy trees – collect leaves from the same trees the mushrooms like to grow under and include these in the mulch.
- The right type of wood/plant material from which the mushrooms like to grow can be collected. However, do not remove too much wood and damage the forest; it is better to grow your own wood and add the mushroom spores to it. The wood can be used as garden borders.

Once you have mushrooms growing, they are easy to maintain, but you **must not** use fungicides or other chemicals that could kill the mushroom spores and base.

Feed the mushrooms in the garden beds with manure, compost, leaves and mulch, or whatever else the mushrooms like.

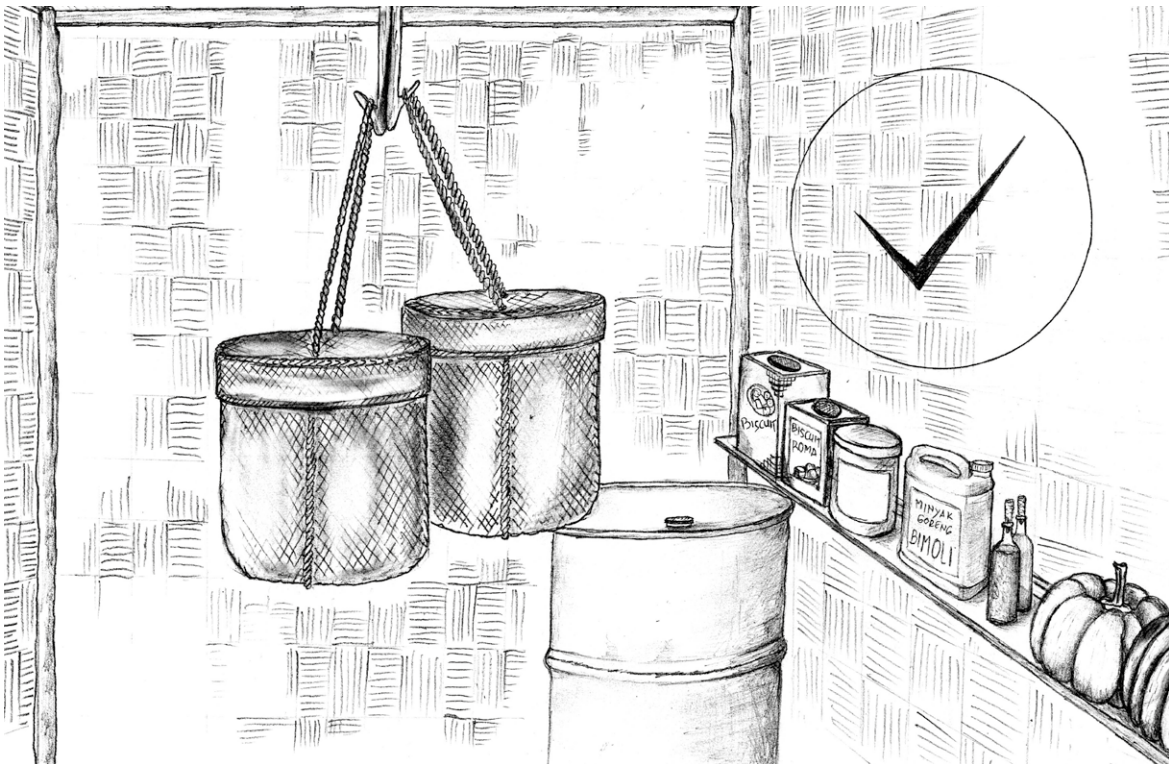
One technique, which works well in Timor-Leste, is to cut up the trunks of old papaya trees, lay them on top of a pile of compost and cover them with thin cardboard or old newspaper. The materials need to be made very wet. Edible mushrooms grow within days and produce for a week. Using the same system, oyster mushrooms like growing on old mango branches, but only if the fungus spores are already present.

Post-harvest storage and use

The time after harvesting is when a lot of food and income can be lost through poor storage preparation, techniques and equipment. There are steps to take to reduce this problem.

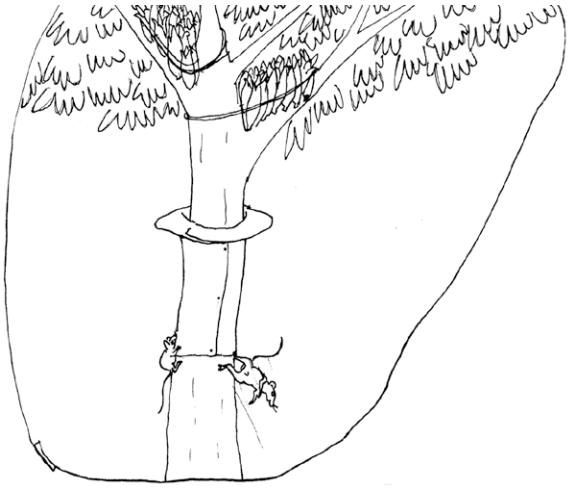
For rice, beans, corn and other dry produce:

- Harvest at the right time.
- Remove the plant material quickly. Removing the plant material reduces insect problems, which is especially important when drying and storing seeds.
- Dry the produce properly. If the produce is stored when it is not properly dry, it rots.
- Store the produce properly.



Good ideas for kitchen food storage

Try to store the produce in dry containers with secure lids. Rice sacks do not keep rats and mice out. Traditional storing techniques keep out large animals but are not as effective at keeping insects, rats and mice away. For trees and storage rooms on poles, attach a metre length sheet of metal around the pole, with the top turned outward at least 20cm, to protect the produce from rats and mice.

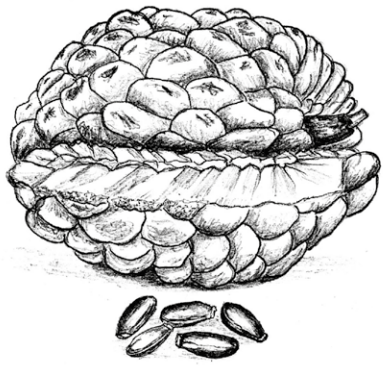


Natural insect protection for stored produce

Natural materials can be added to the grains or beans to provide protection from insects:

- **Ash:** Ash from plants helps to reduce pest attack. DO NOT use ash from rubbish fires. For large amounts of produce use 2% by weight of grain. (e.g. for 100kg of grains/beans used 2kg of ash) For small containers, including a 1cm layer of ash at the top and bottom is good. Ash from casuarina, eucalyptus, mango, tamarind and rice husks works well.
- **Neem leaves (dried):** Use a layer approximately 2cm thick of leaves on top of the grains/beans. For small containers include a leaf layer about 1cm thick.
- **Peel (dried):** The peel (skin) from lemons, grapefruits, limes, oranges and mandarins is effective for repelling pests from stored produce.

Neem leaves



Custard apple with seeds

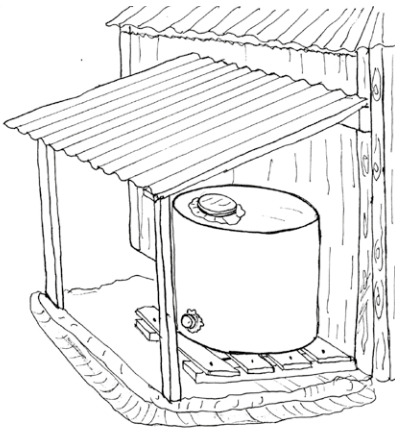
These following methods are NOT for grains or beans that are for eating:

- **Eucalypt:** Use 10 to 20 fresh or dried crushed leaves. Add the leaves to the stored grains/beans to repel pests.
- **Tobacco leaf:** Be very careful because tobacco is very strong. Only use old, dry leaves, and only use them in large storage silos. Place a layer of leaves approximately 2cm thick on top of the stored grains/beans.
- **Custard apple (*Annona squamosa*):** Dry the seeds and crush them into a powder. Mix in a quarter of a cup of the powder per large container of produce.

There are many local plants and recipes for protecting produce; research and use local, tested materials whenever possible.

Storage systems for food

CONTAINERS FOR PRODUCE



Grain/bean storage silos, made from metal sheets, are great long-term storage containers. They protect your valuable produce by reducing insect and animal attacks. Metal silos also lengthen the produce storage time.

When using silos or other large storage containers:

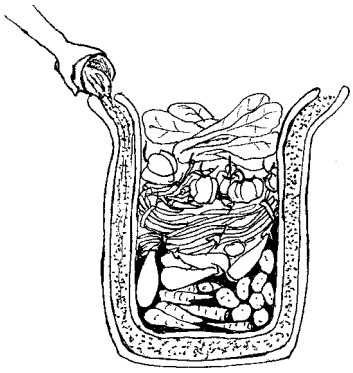
- Clean the produce.
- Put the silo on a stand.
- Put the silo under a roof to protect it from rain and sun.
- Use tyre tubes to close the silo openings.

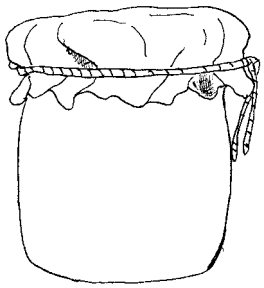
Use ash, neem or other safe materials for protecting your food from insects and pests. Do not use anything poisonous or that could affect the taste, and wash the grains or beans well before using them.

FRESH HARVESTS

For fresh produce, such as tomatoes, lettuces, snake beans, snow peas, cabbages:

- Harvest the produce at the right time of ripeness. This varies; most vegetables are picked as they are ripe, and most fruit is picked a little under ripe as it keeps ripening after being picked.
- Harvest at the right time of day; early morning is usually best. Have a damp cloth to cover the produce immediately after it is picked.
- Fresh produce must be stored in a cool, dry place, free from insects and animals if possible, until eaten, sold or transported. Spray it with clean water occasionally to keep the produce moist.
- Transport the produce carefully, away from the sun, as cool as possible and prevent bruising. The food lasts many days longer if it is carefully handled.
- For produce stored at home or in local markets, use clay pots with a damp cloth on top. The produce stays fresher for many days longer.





GROUND STORAGE

For root vegetables, such as potatoes, sweet potatoes, cassava, yams, taro:

- For eating – the vegetables can be stored in the ground until they are eaten.
- For selling – harvest the vegetables as carefully as possible. Any cuts or bruises make them rot much faster.
- When the vegetables are harvested they must be stored in a dry, cool place out of the sun and protected from animals and insects. You can use wood-fire ash for insect and animal protection. Simply wash it off before selling or eating.
- Carrots are different because they become hard and bitter if they are left in the ground too long. Store them in sand to make them last longer.
- Sand can also be used to store all root vegetables.

Top: Cross section of two clay pots with sand in between

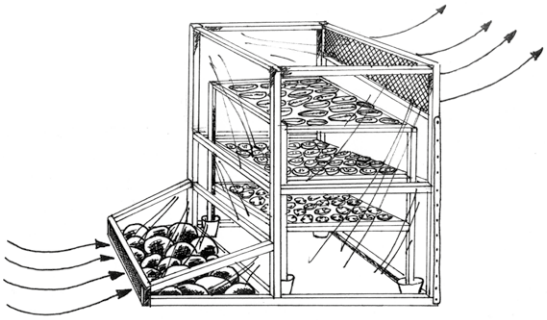
Middle: Covering clay pots with wet cloth

Bottom: Ash provides storage protection

Using excess produce

Sometimes there is more produce than can be eaten, sold or traded. Rather than letting it rot and be wasted it can be processed for long-term storage.

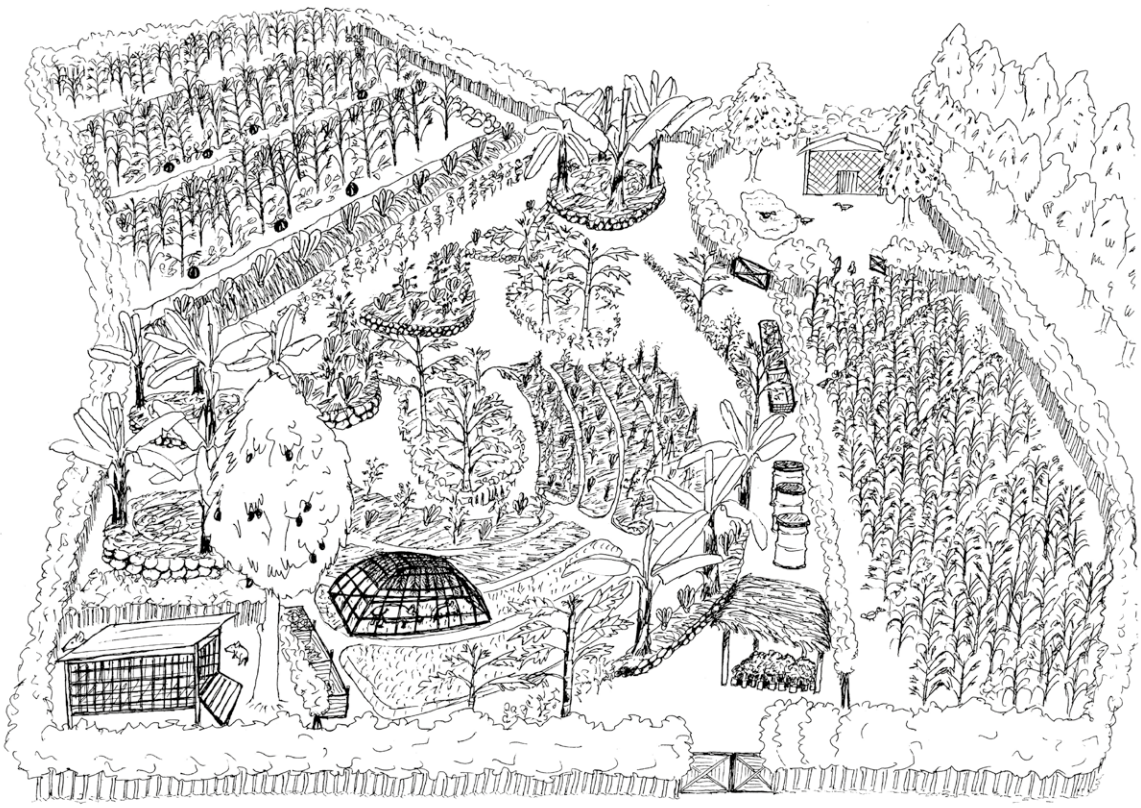
- Solar driers can be used to dry vegetables or fruit to be stored for later use. Look in the Food, health and nutrition chapter (**Ch 8**) for how to make and use solar driers. Sauces, preserves, jams, and more can be made from vegetables and fruit.
- Excess food can also be used to make feed for pigs or chickens, or turned into compost.



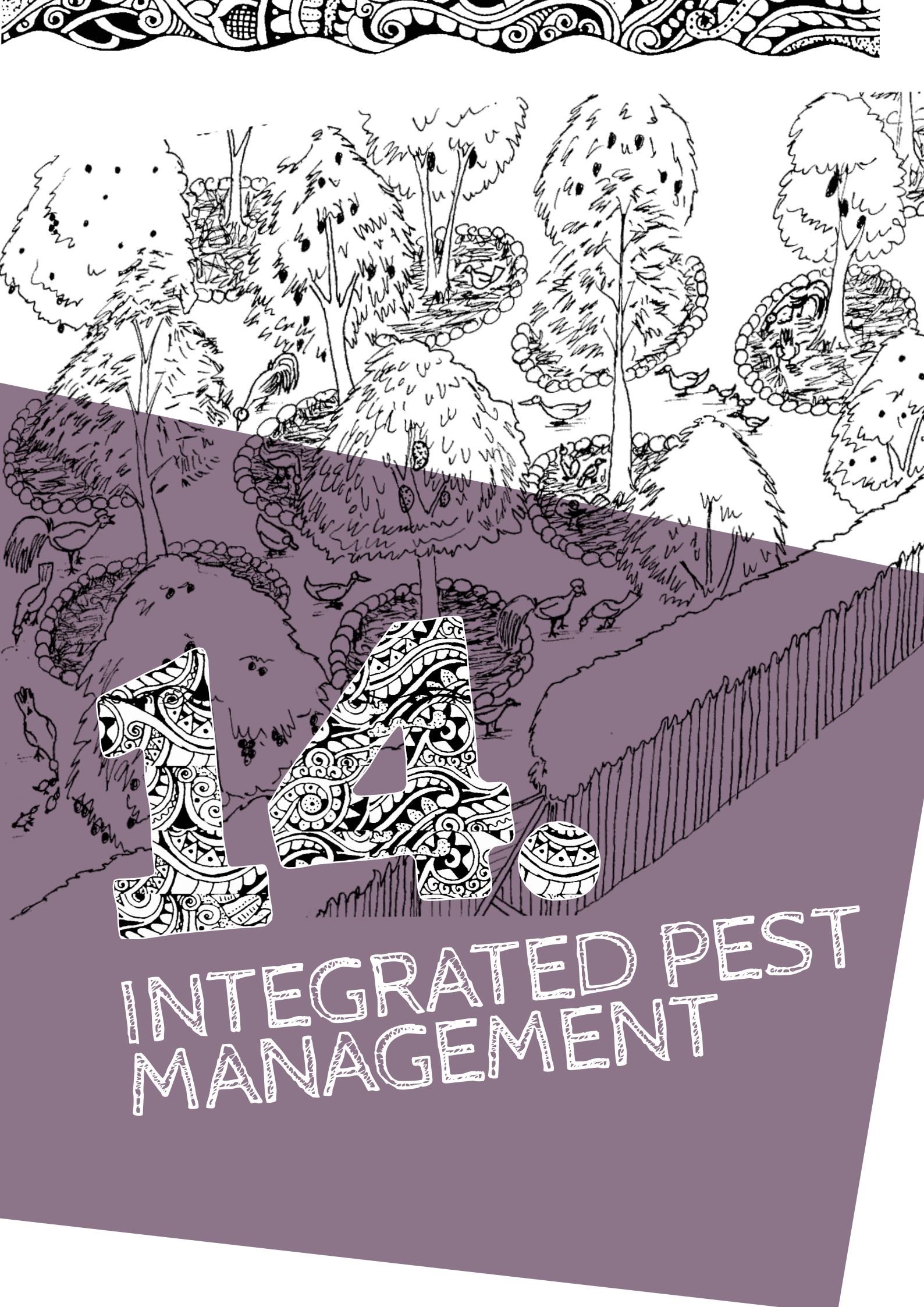
Food production must be improved and made more resilient.

Protection of the natural environment must also take place.

These two goals are essential for future prosperity, and can be achieved together if good design, strategies and techniques are used. Organic, diverse and integrated food production systems, focused on regenerating soil and maximising water harvesting and use is what will make agriculture truly sustainable.



SUSTAINABLE AGRICULTURE
CHAPTER NOTES



14. INTEGRATED PEST MANAGEMENT

14. INTEGRATED PEST MANAGEMENT

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Long-term pest and disease management solutions must bring back a natural balance between agriculture, gardens and the natural environment. Scientists have known for a long time that over 90% of insects are actually harmless or beneficial to crops and other plants. Now they realise that this is similar for bacteria and fungi. We need them in the garden and in the soil to maintain good production, so we must use natural growing techniques!

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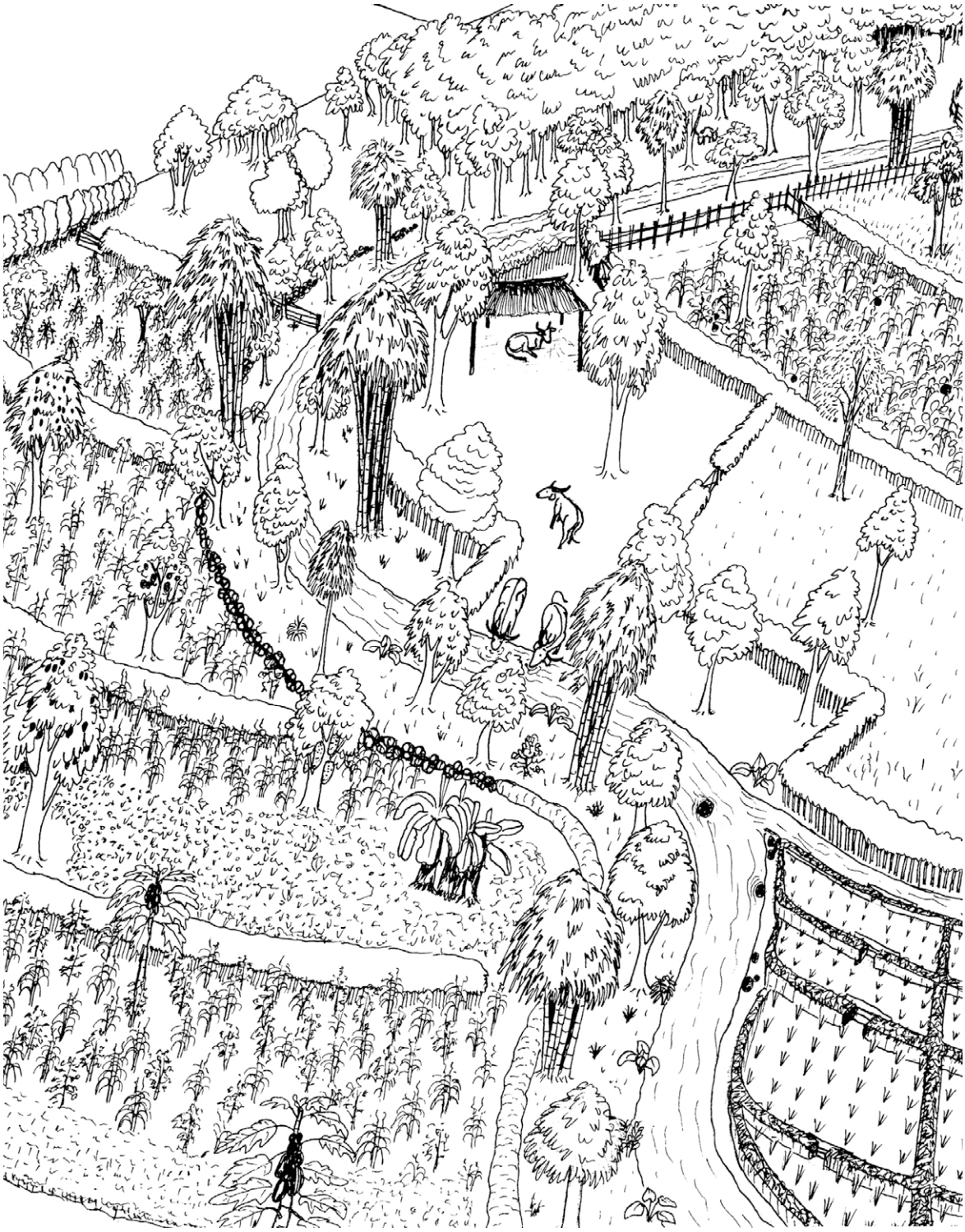
Every element of the environment - and that includes us - is connected to every other part. What happens to one element affects every other element of the system or environment. This is an important philosophy behind IPM and future sustainability.



What is Integrated Pest Management?

Integrated Pest Management (IPM) combines different natural strategies and techniques for pest management to:

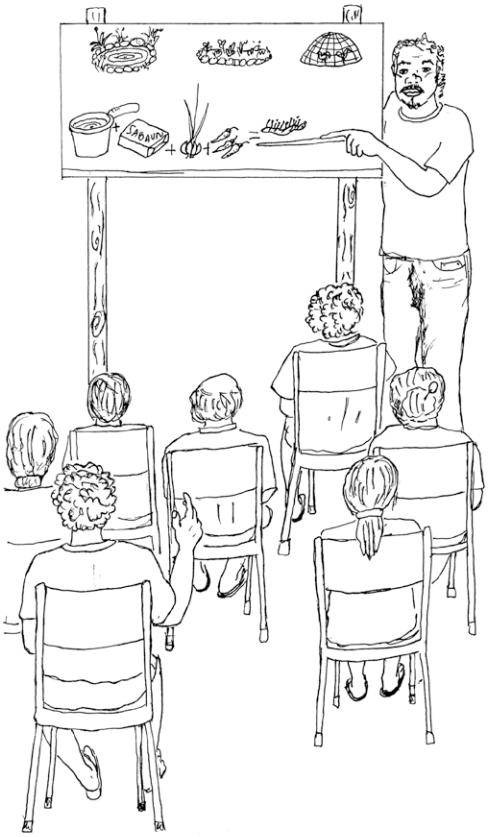
- Reduce the chances of pest problems happening.
- Reduce the size of the pest problem if it does happen.
- Use natural treatments for problems that persist.

Integrated Pest Management applies to all levels of agriculture from small family gardens and market gardens to large areas of crops, rice production, fruit trees and all mixed systems.

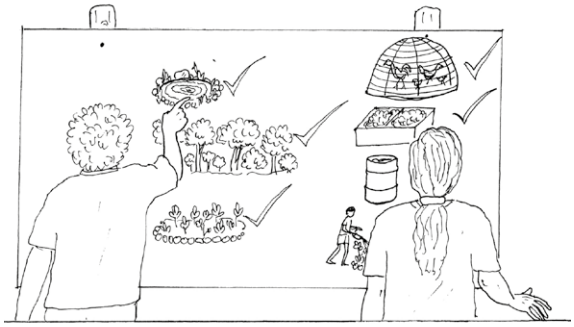
We need to observe and understand how different elements in a system work and how they can work together: e.g. soil, insects, plants and trees, birds, animals, water, people, technology.

Understanding the elements means:

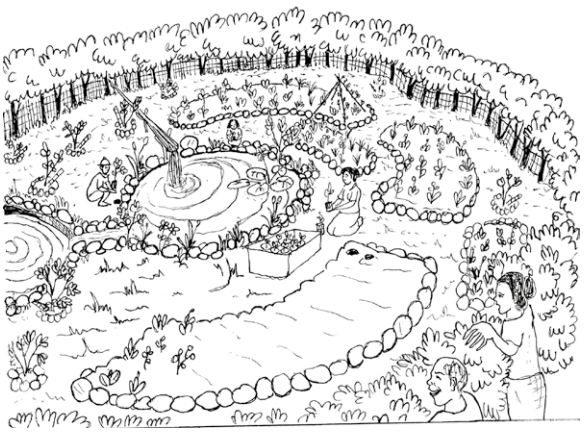
- We use fewer resources and less expensive products because the farm maintains itself more and more. Also, the necessary resources are mostly found locally.
- There is continual improvement – not gradual destruction – of the soil, plants and environment.
- Overall productivity of the land increases.
- There is increased diversity and resilience to pests, diseases and extreme weather.
- People's health improves.



1. Mery and Anselmo attend an IPM workshop



2. Anselmo says "I want to build a pond to increase our pest predators and then we can raise fish too"



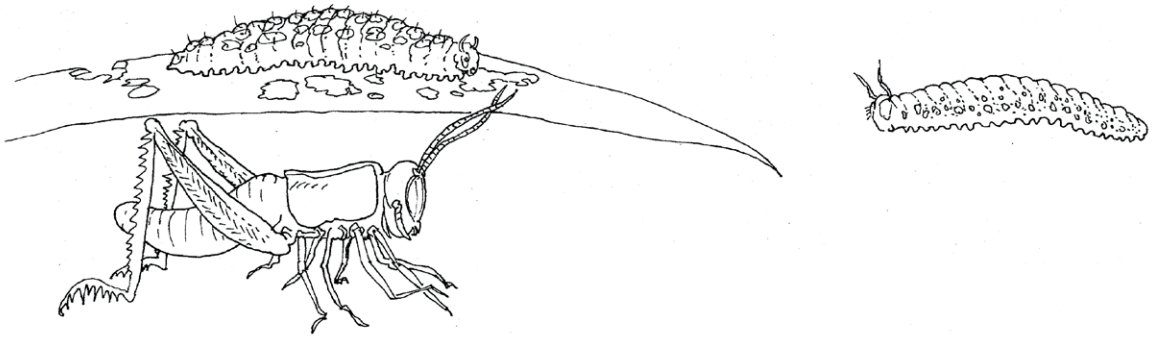
3. The neighbours watch and ask "What are Mery and Anselmo doing?"

What are pests and diseases?

This chapter covers the natural management of pests (some insects and other small animals) and diseases (fungi, bacteria and viruses). Solutions and control methods are in separate sections.

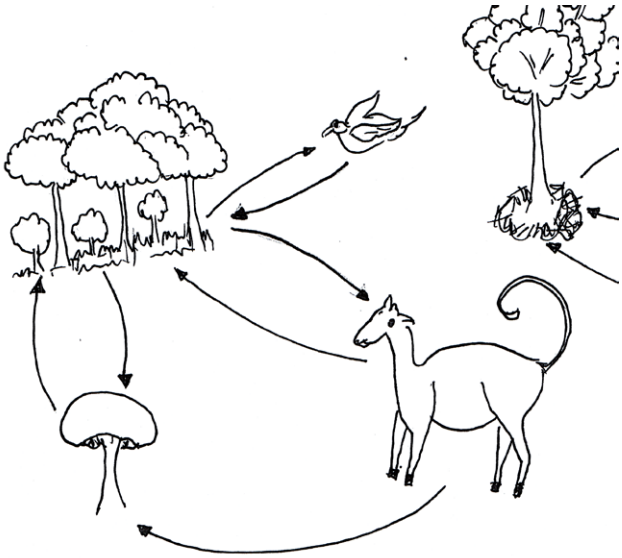
INSECTS

The small number that are pests can sometimes be seen on plants or in the soil and usually have different life cycle stages. They tend to damage plants by chewing holes in roots, leaves and fruit or by sucking sap out of the leaves, stems and fruit.



FUNGI

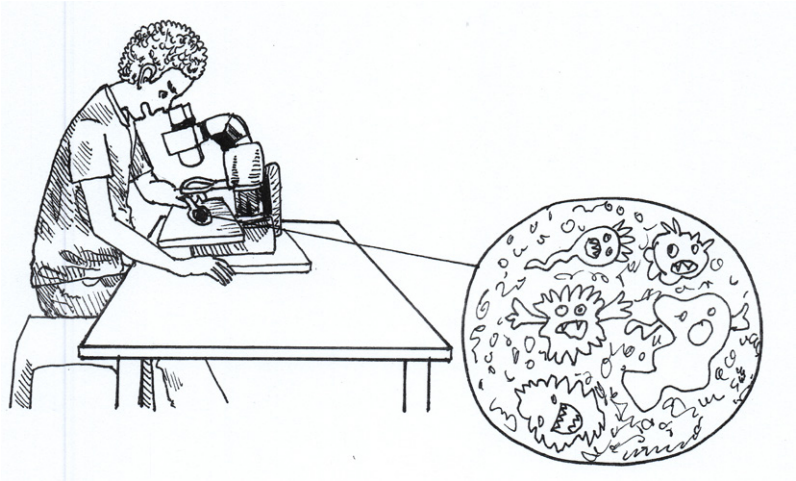
Are very small, live above and below the ground and can sometimes be seen as mushrooms. They are an essential part of nature's nutrient cycle as they are the main decomposers in a system and many fungi have direct beneficial relationships with plants through their roots. A few types of fungi live on plants and can cause problems to all parts of plants. Signs of fungi may be a powdery substance under the leaves, rotten patches, black spots on stems, leaves and fruit or wilting because of rotten roots. Fungi spread through rain that is splashed up from soil on to plants or carried by the wind from one plant to another. Soil fungi spread quickly when the soil is regularly dug and turned.



Fungi as part of nature's cycle

BACTERIA AND VIRUSES

Are only visible with a microscope. They cause rot in roots and stems, damage leaves that die back, create black spots and other symptoms. They spread through water, soil and affected plants.

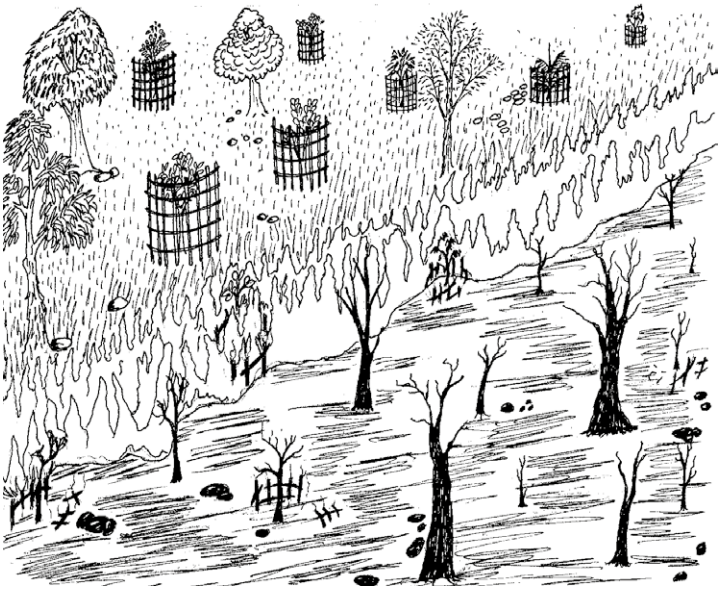


Why do pests occur?

Pest problems occur because a system is not in balance.

There are different reasons:

- Fire, flooding and land clearing.
- Using large areas of land for only one crop – monoculture.
- The introduction of a pest into an area.
- The destruction of pest predators by using chemical pesticides and removing pest predator habitats.
- Changing seasons.
- Climate change creating unusual weather patterns which place stress on plants.



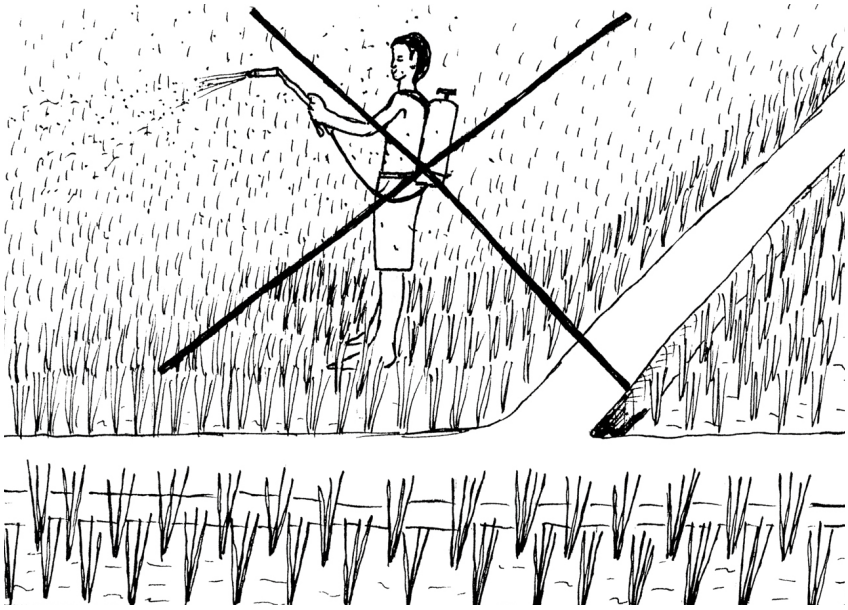
Fire creates imbalance by removing habitats and damaging the soil

Changing from chemical to organic

Using chemical sprays to control pests has proven to be ineffectual over the long term and actually creates more pests! Pest damage on crops has increased from under 5% before chemical pesticides were used, to over 20% now.

The reasons for this are:

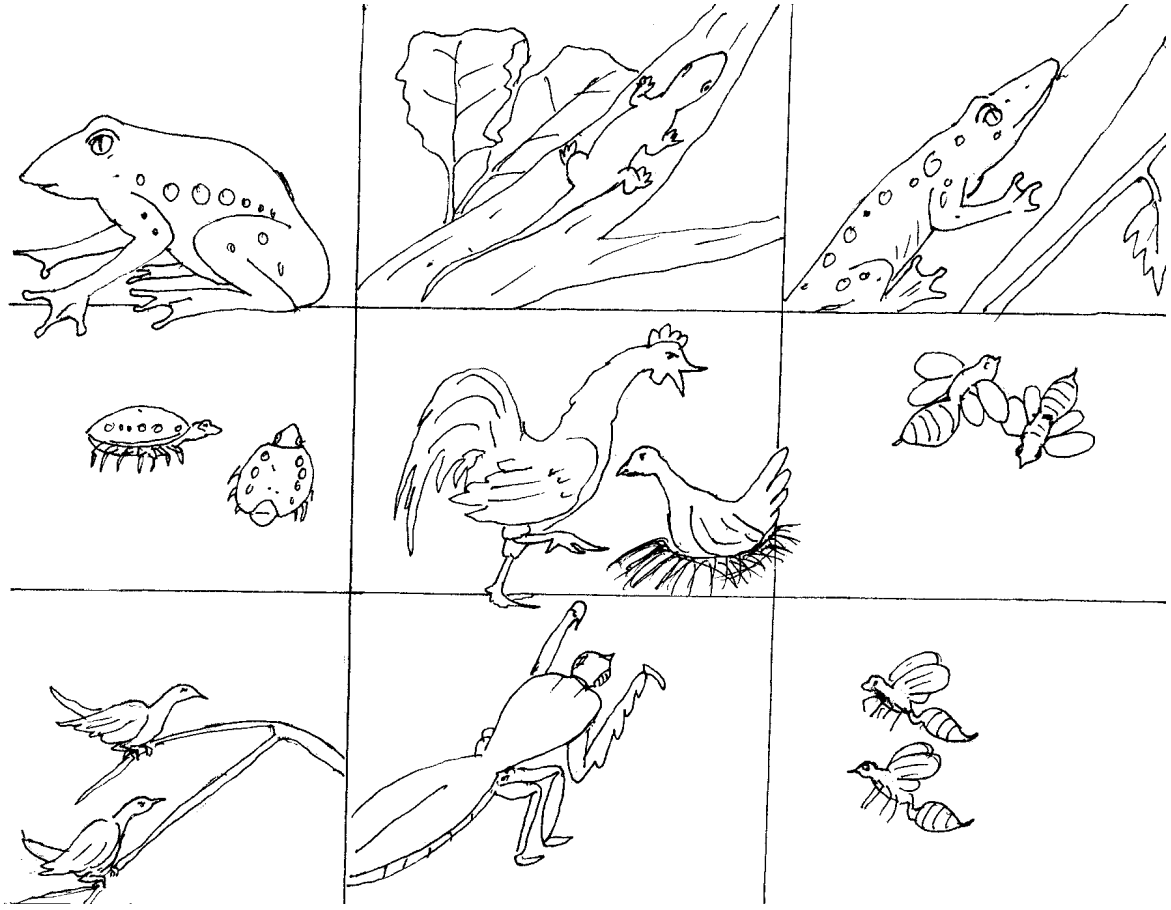
- Pesticides kill all insects, not just the pests, including pest predators which are the natural enemy of pests. After spraying, pest predators do not usually reappear as quickly as the pests (as they have slower reproductive rates). Some insecticides are more toxic to predators and parasites than others, and pests develop resistance to the poison. Individual insects have different levels of resistance to the sprays; every time you spray an insect population you change the balance between susceptible and resistant individuals. The resistant individual pests survive and reproduce, therefore creating pesticide resistance.
- Pesticide use is usually combined with other pest-increasing practices such as monoculture, cropping and removing pest-predator habitats.



Changing from conventional methods and chemical sprays to organic and IPM methods initially may still require natural pesticides as often as you previously used chemical pesticides. This is until other pest control methods, such as improved soil quality, encouraging pest predators, good crop and land management and pest prevention techniques, restore the balance.

There are many different types of natural pesticides. They are made from traditionally known materials or from new recipes using locally available materials.

In time, even natural pesticides are only rarely needed or not at all. To speed up a successful transition, allow some pests to breed up in small numbers to attract pest predators quickly into the garden. Make sure you also create good habitats for your pest predators so they breed and stay in your garden.

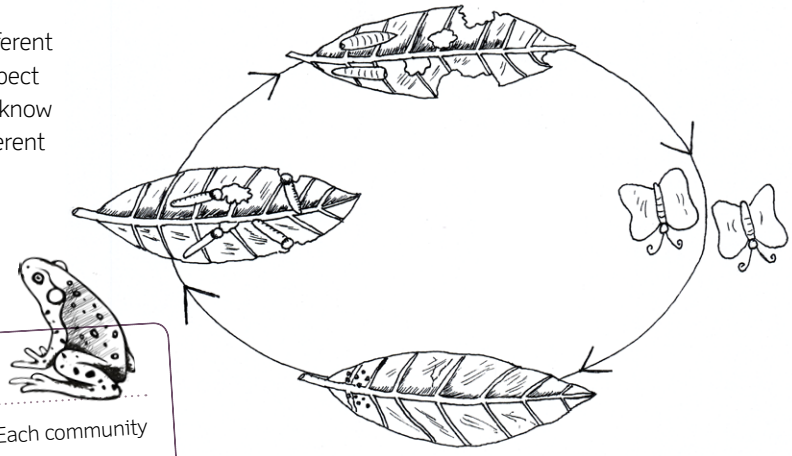


Pest predators

Remember, your goal is to create a self-maintaining system that uses as many local resources as possible.

Local knowledge and observation

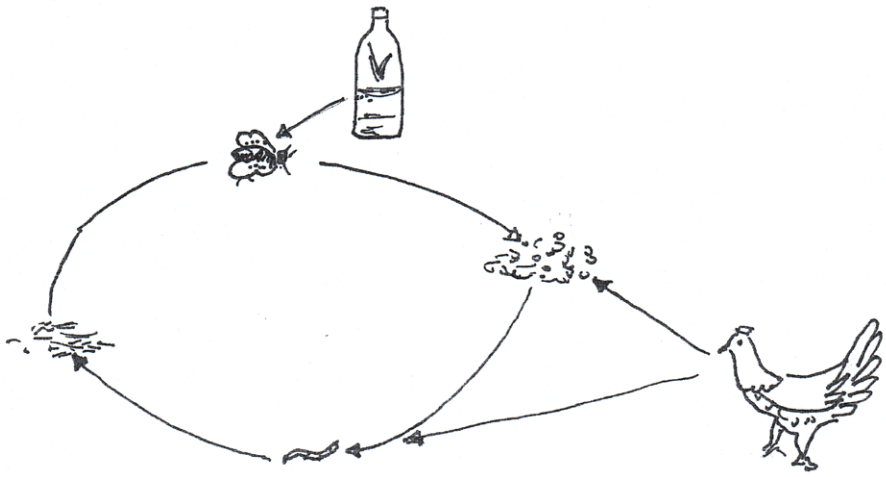
Learn about the life cycles of the different pests and at what time of year to expect their attacks. It is also important to know which pest predators attack the different pests and at which stage of their life cycles.



SMART IDEA:

Make a list in your community of plant pests. Each community has different pests and different treatments. Based on your own experience and your community's knowledge, use the following list as an example to create a complete list of pests and how to prevent and/or control them.

PEST	WHICH PLANT AND PARTS OF THE PLANT DOES IT ATTACK?	LIFE CYCLE	WHAT TIME OF YEAR DOES IT ATTACK?	PEST PREDATOR	PREVENTATIVE MEASURES	EFFECTIVE NATURAL PESTICIDES
Aphid	New growth, stems, leaves and flowers	Egg - pupae - adult	All year	Ladybirds, lacewing wasps	Mixed cropping, crop rotation	Soapy water, neem spray
Snails	Leaves, stems, young plants	Egg - adult	Mostly in the wet season	Birds, humans	Wood ash, snail traps, citrus skin, eat them	Crushed insect spray, lime powder spray
Your own example…						
Your own example…						



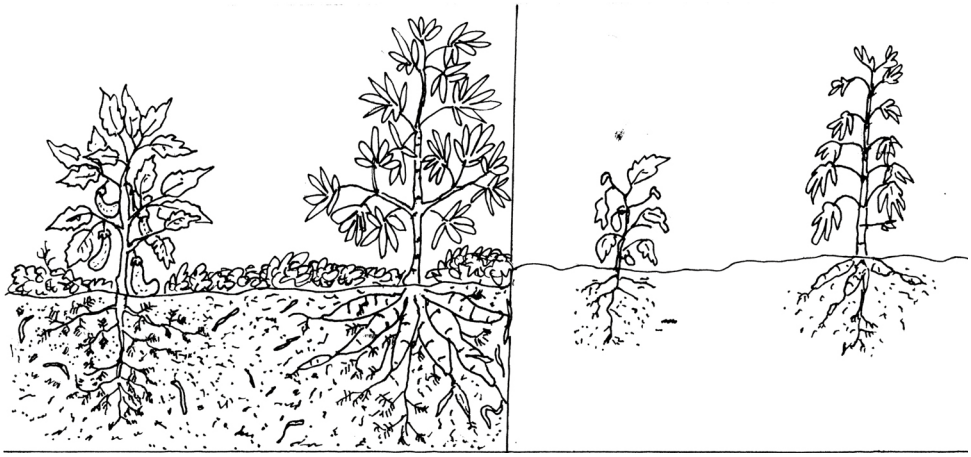
Fruit fly lifecycle with preventative measures

IPM strategies and techniques

1. Importance of healthy living soil

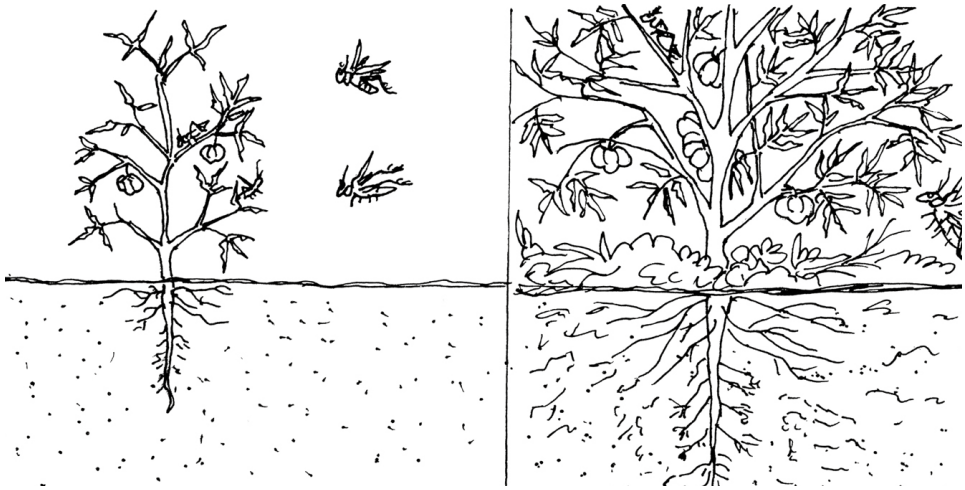
Healthy living soil containing all the different nutrients that plants need is **the most important IPM strategy or technique** for preventing pest and disease problems. If a person is healthy, they usually live longer, rarely get sick and recover faster when they are sick. They are stronger, able to work more and produce healthier children. **It is the same for plants!!!!** The basis for good plant health is the same as for people:

- A balanced variety of nutrients and minerals (a good variety of food).
- Growing in healthy, living (full of worms, good fungi and bacteria), non-compacted, mulched soil, protected from erosion by edging, terracing or swales (a comfortable house).
- Water, sun and a healthy environment.



Healthy soil Unhealthy soil

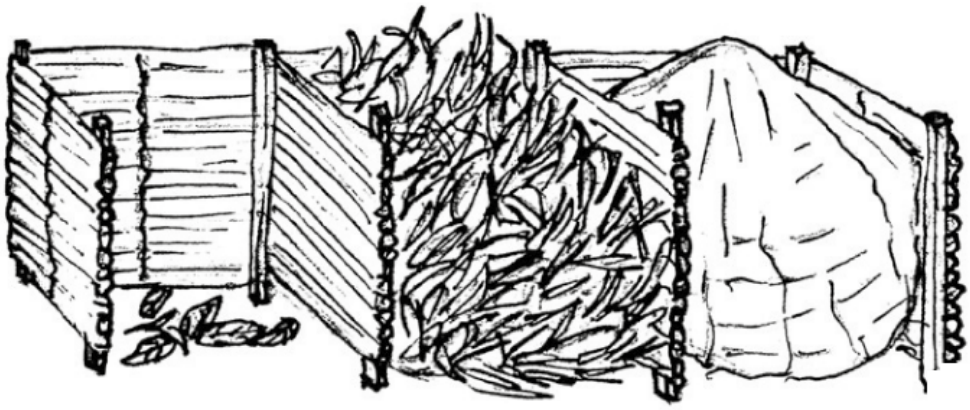
If a plant is healthy, it grows stronger and is less likely to be attacked by pests and disease. If it is attacked, it suffers damage more slowly and recovers more quickly.



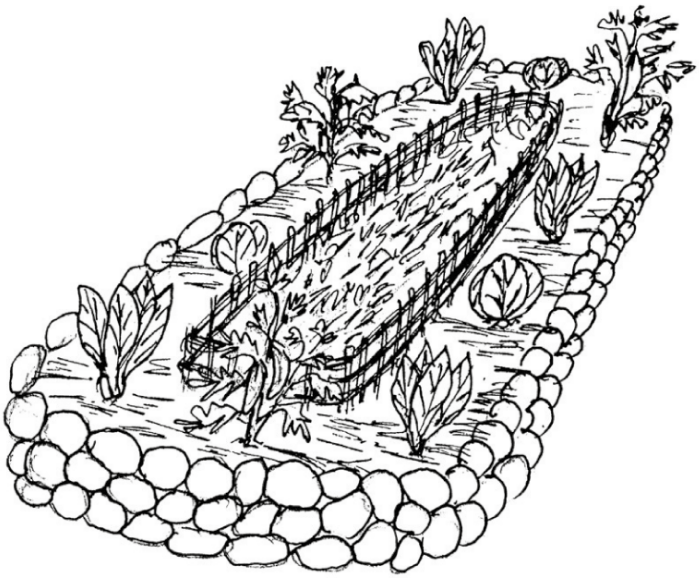
Low resistance High resistance

Providing good plant food and soil saves a lot of time, effort and money from not having to control many pest problems. With good, natural techniques the soil improves each year, growing healthier plants with fewer problems.

Compost also reduces the disease potential for plants because it contains good bacteria and other micro-organisms that remove some pathogens from the soil.

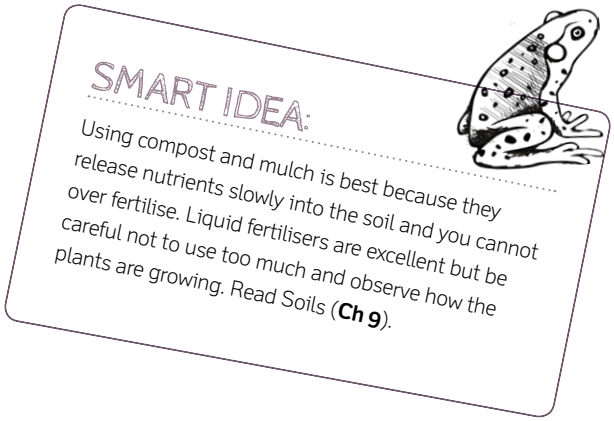


Compost bays



Compost trench in a garden bed

Too much fertiliser or imbalanced fertilising makes a plant grow too fast, giving it thin stems and making it more at risk of insect attack. This can be from using chemical fertilisers or too much liquid fertiliser.

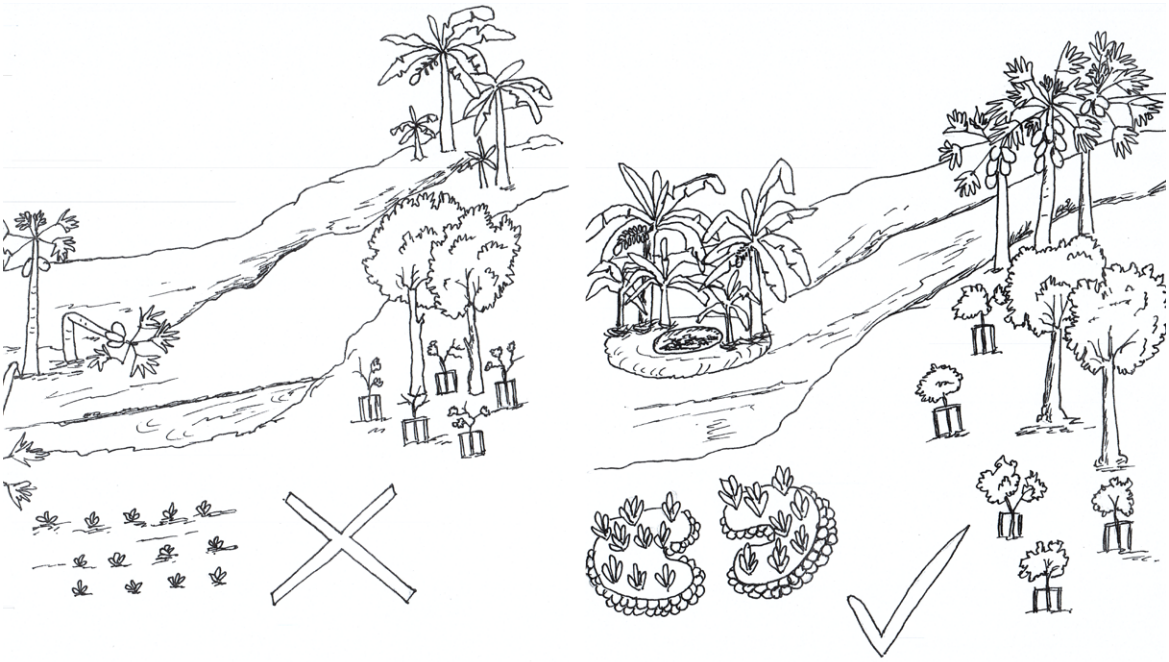


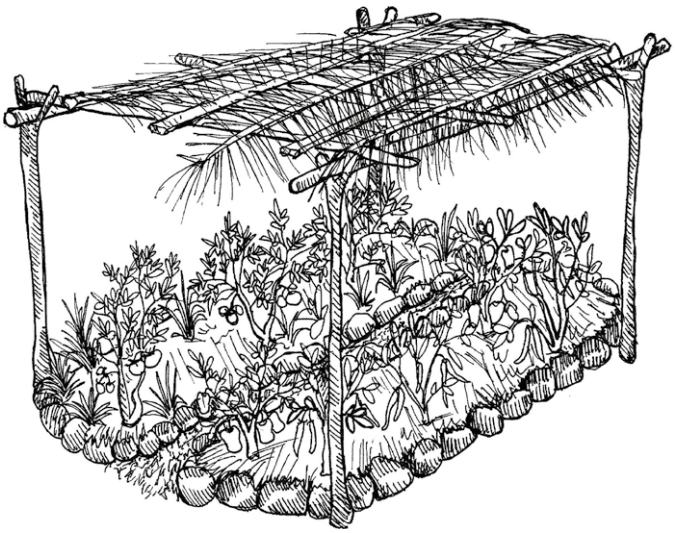
2. Best growing conditions

To be healthy and resilient, plants need to grow in conditions to which they are best suited.

This includes:

- The right amount of water, sunlight and space.
- Appropriate soil conditions including good water drainage.
- Protection from strong or salty winds and the right amount of air flow.
- The right season or time of year.





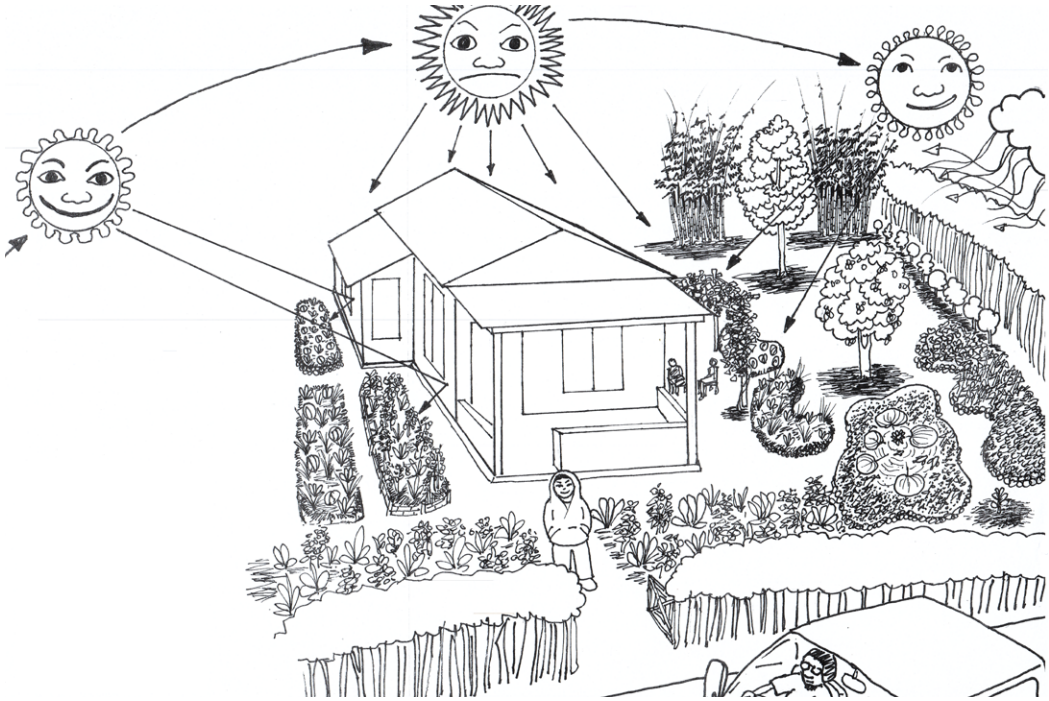
Raised beds create better drainage and shade in the period before the wet season reduces extreme heat. Both create better growing conditions for plants

The right choice of growing conditions reduces pest problems and especially disease/ fungal problems.

Different plants require different conditions, which are called microclimates. Some like very dry soil, some like moist soil, some like shade, some like full sun, etc. Most plants prefer to be protected from strong or salty winds from the sea, which stress the plants and make them vulnerable.

There are many different microclimates on each piece of land, and you can create new microclimates to suit particular crops that otherwise would not grow well. For example, more or less water in the soil, more sheltered, using walls to reflect heat at night in high altitude tropical regions. Read more on microclimates in Permaculture design strategies and techniques (**Ch 3**).

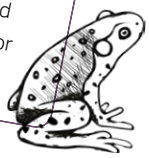
If plants are matched with their preferred conditions, they grow better and are much more disease resistant. This is true for all plants, vegetables and trees. Group the plants together that enjoy similar growing conditions.



Creating and using good microclimates around the house

SMART IDEA:

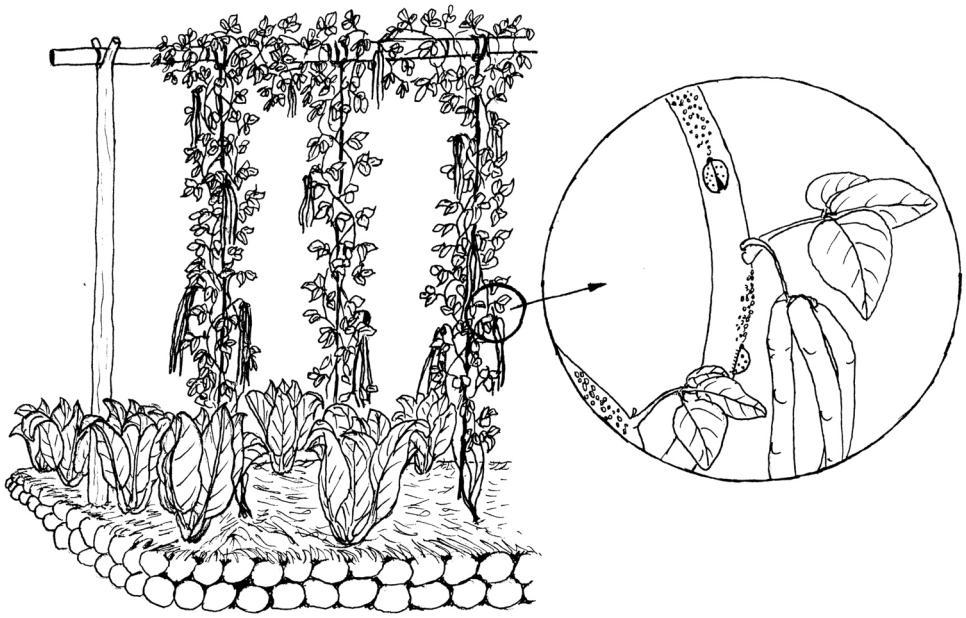
Trees planted next to the garden can act as a windbreak, a home for pest predators and provide food, medicine, nuts or other resources.



3. Natural pest predators

In a healthy balanced system most pests are kept under control by natural pest predators.

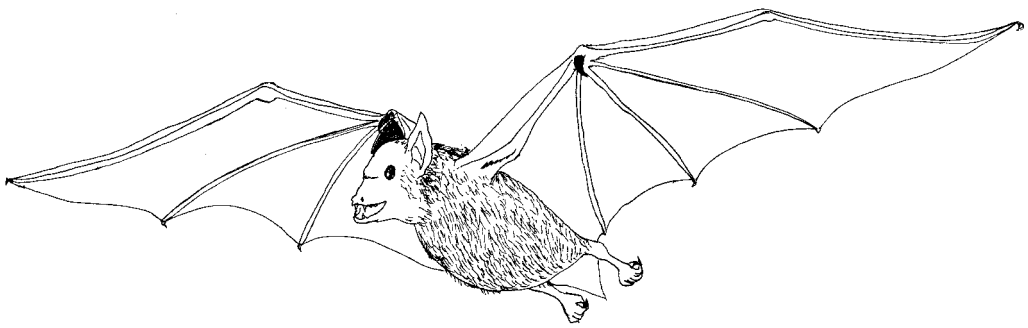
Each plant has pests that attack it, and each pest has predators that eat them.



Ladybird eating aphids

There are four types of pest predators:

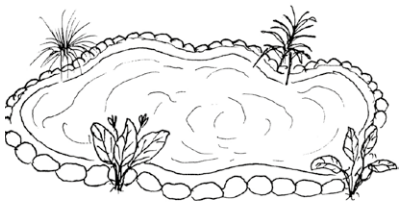
1. **Predators that eat insects:** Birds, lizards, frogs, bats, dragonflies, wasps, spiders, praying mantises, ladybirds, ground beetles, lacewings and even some flies are effective natural pest predators that do most of your pest control work for you. You just need to attract them by providing them with a home, some water and extra food, and they will happily live in your garden!
2. **Predators that eat pest animals:** Eagles, owls, crows, kingfishers and snakes eat mice and rats. This is very important for reducing damage to grain crops.
3. **Parasites:** Most of these are insects (e.g. wasps) that lay eggs inside the body of a living insect called a host. The parasite feeds on its host until it finally kills it, and the adult parasite emerges from the dead host to search for more insects in which to lay its eggs. Parasite pest control is slower but very effective.
4. **Diseases** carried by viruses and fungi can infect and kill insects, and whole populations can be wiped out quickly.



Pest predator

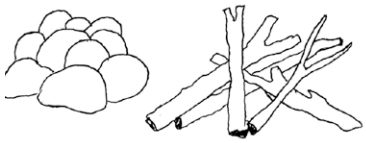
Here are some homes and attractive aspects for natural pest predators that eat insects, pest animals and some parasites:

Ponds – for birds, frogs, dragonflies, bees, wasps and fish (some fish eat mosquito larvae)



Dead trees and branches – dead trees and branches provide homes for many birds and animals that are predators of rats and mice

Rocks, rotting wood – lizards, spiders



Flowers, shrubs, small trees, vines – wasps, bees, spiders, ladybirds, praying mantises, beetles, lacewings

Trees – for birds, bats, wasps, bees and spiders

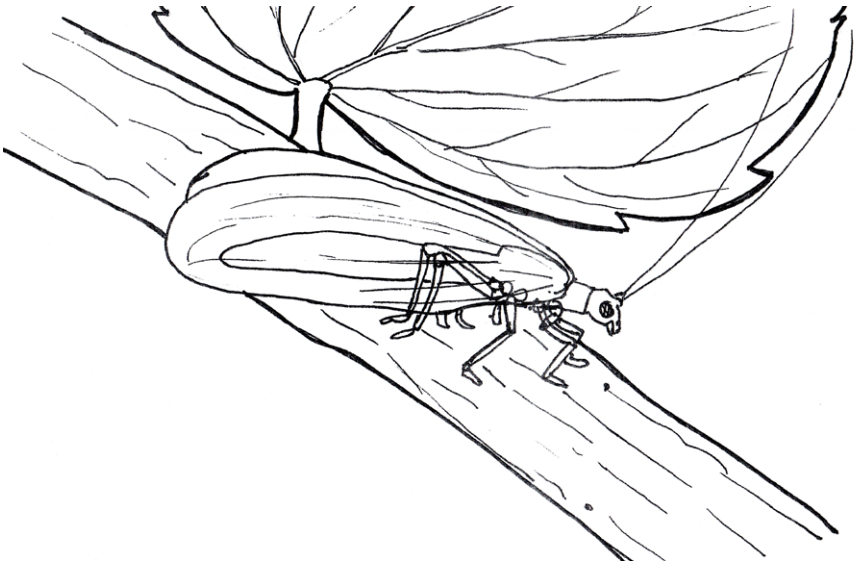
These features are important to include in or next to your garden. Once established these features require little time or maintenance. Plants with many small flowers are better than plants with a few big flowers. Dill, parsley, coriander, cumin and other plants from the Apiaceae (or Umbelliferae) family are excellent, and other small-flowered plants are great too. Even if you do not grow them for food, grow some to reduce pest problems and increase pollination.

It can take a year or two to attract a good natural pest predator population. Other pest control methods may need to be used while this happens. Once they are on your land predator bugs take three weeks to breed up. If you do use a natural pesticide, leave a small section with pests on it so that some predators can still breed. They can then eat the pests you have left and, more importantly, they will remove future pest outbreaks too.

Beware: chemical pesticides and some natural pesticides also kill pest predators and other beneficial insects. They damage or even destroy beneficial insect populations. Use natural pesticides very carefully, only when necessary, and only after trying all other methods.

BIOLOGICAL CONTROL

Biological control is the introduction of a pest predator or control technique into an area that has a large pest problem. The pest could be an insect, plant, animal or bird. The solution can be a predator that eats insects, or a parasite or a disease that kills the pest. The result is that the pest problem is stopped, most times, without the need to use pesticides. Usually biological controls are released by the government agriculture departments or can be bought from them. Examples include a parasite that kills spider mites, a moth that controls prickly pear cactus and green lacewings (family Chrysopidae), a predator of aphids, young caterpillars, scales, insect eggs and other small organisms.



Green Lacewing

Important: **Do some research before using the biological control to make sure that it is safe. Only use controls that have been well tested and proven not to create problems in the environmen**t. Many controls have been successful, but there are big failures as well, such as introducing the cane toad into Australia to control the sugarcane beetle. Now the cane toad is one of Australia's biggest pest problems and it did not even control the beetle!

Cane toad

4. Healthy environment

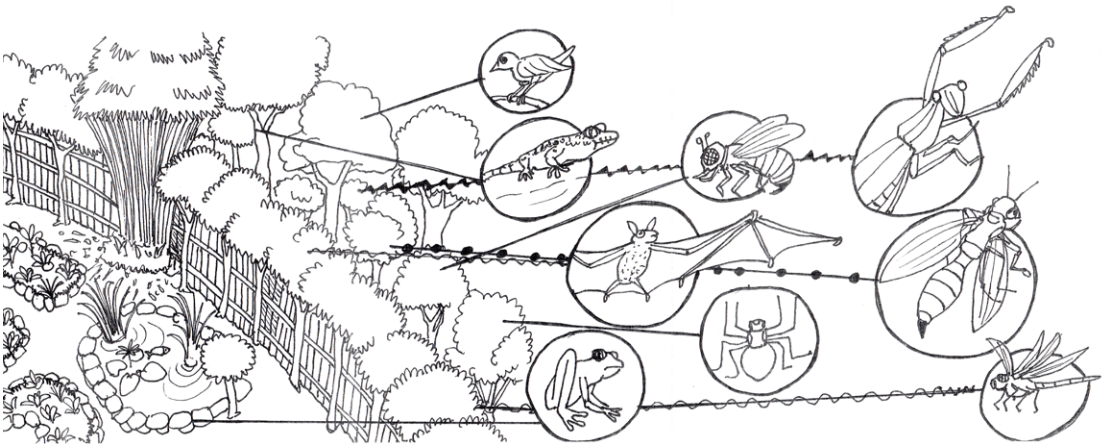
If the land surrounding the agricultural land is healthy and diverse, the chances of large pest problems are greatly reduced. It is an essential part of keeping the system in balance, and the result of a healthy environment is that all other IPM techniques are enhanced.

This includes rivers, forests, steep-sloped land, the house area, etc. Protecting water sources, stopping burning, preventing erosion and conducting reforestation are important steps towards achieving a healthy environment.

These steps reduce strong winds that can stress plants causing them to be more susceptible to pests and diseases, make water supplies more secure, and protect the soil.

DIVERSITY

A diversity of plants and natural habitats in the garden and the surrounding environment leads to healthy and diverse predator populations. The results are more diversity and a balance of insects providing natural control of pest populations.



Homes for pest predators

5. Use non-hybrid, open pollinated seeds

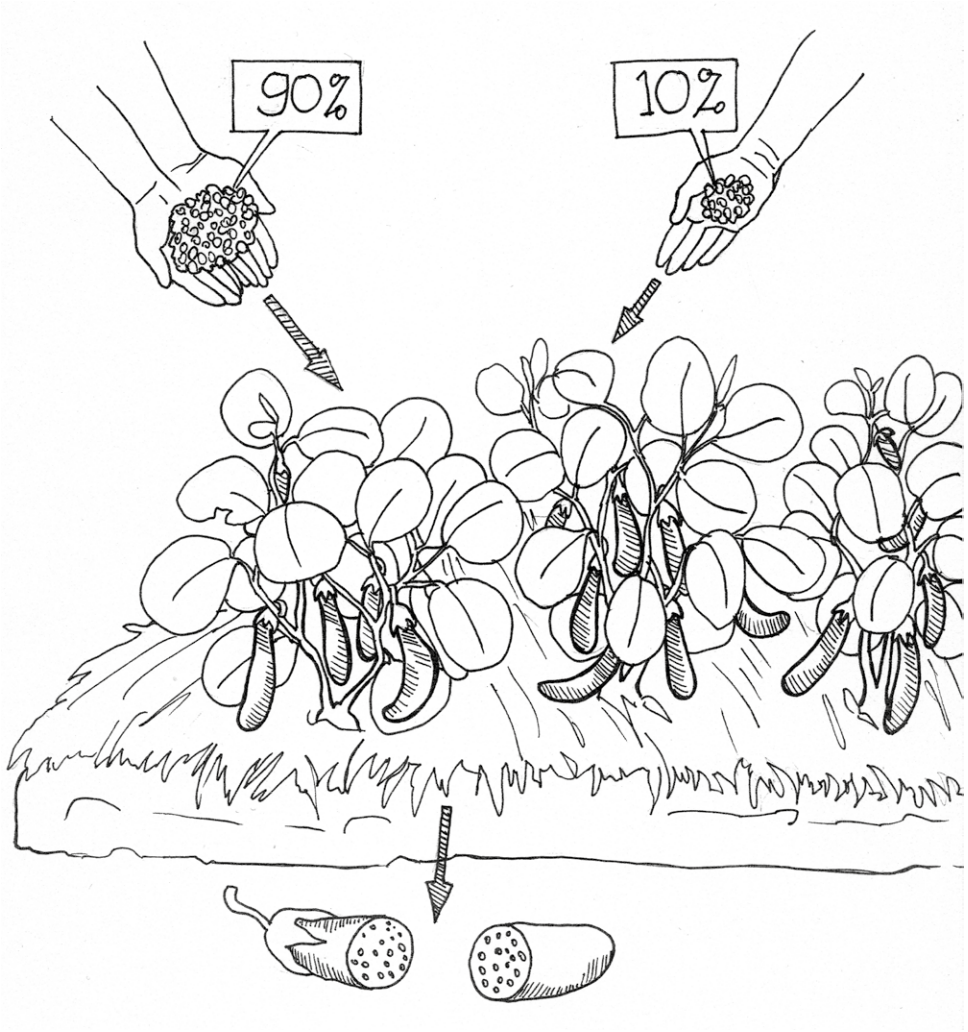
Saving, using and improving good quality local seeds are very important. It increases the natural pest and disease resistance of the plants. Non-hybrid, open pollinated seeds are best because these types of seeds stay the same and their quality improves when you use good seed-saving techniques.

Save some seeds from the **best** plants of each crop – they are the most resistant to pests and diseases – so the plants become more used to the local climate, soils and conditions. Future crops will, therefore, grow better and be more resistant.

Hybrid seeds (not F1 Hybrid types) can usually be used for seed saving; however, the seeds can vary in their characteristics and the results for the next crop are unknown. The plants are not familiar with the local conditions and may suffer problems because of that but they improve over time. Seeds from very different microclimates can also struggle to grow well.

F1 hybrid and Genetically Modified (GM) hybrid seeds can never be used for seed saving.

It is good to refresh your seed stock every few years to keep it healthy and productivity high. To do this you need to cross your existing seed stock (90%) with proven good quality seed stock (10%) from somewhere else.



Look at Seeds and propagation (**Ch 11**) for more explanation.

SMART IDEA:

A two season seed saving plan can increase pest and disease resistance.

First season: choose the two most pest and disease resistant plants in a crop, even if they are not the best for size and production.

Second season: grow those seeds in a small garden bed and select the BEST plants for seed saving according to the combination of factors – pest/disease resistance, highly productive, tasty, slow to set seed. This way you will have seed stock which is highly pest and disease resistant.

6. Good crop management

Planting many crops together, crop rotation and using natural patterns are some crop management techniques. Good crop management reduces pest numbers and minimises disease/fungal problems.

If a farmer plants a large area with only one crop (monoculture), there is more chance that pests or diseases will come and in larger numbers. When pests or diseases attack in large numbers they are hard and expensive to control and cause great damage. This happens with monoculture because:

- It is easy for the pest or disease to spread from one plant to the next.
- There are large amounts of food available for the pest.
- Pest numbers can build up very quickly.
- Usually there is not the number of pest predators needed to control a pest attack. This is because there are no habitats around for pest predators.

Bad crop management: Insects attacking a monoculture crop of corn

It is much better to combine different plants in rows, sections or planted together.

This slows down pests spreading from plant to plant, and helps to reduce the number of pests. Problems are, therefore, much easier to treat. Make sure you include some habitat plants, such as flowering annuals and perennials.

Good mixed cropping

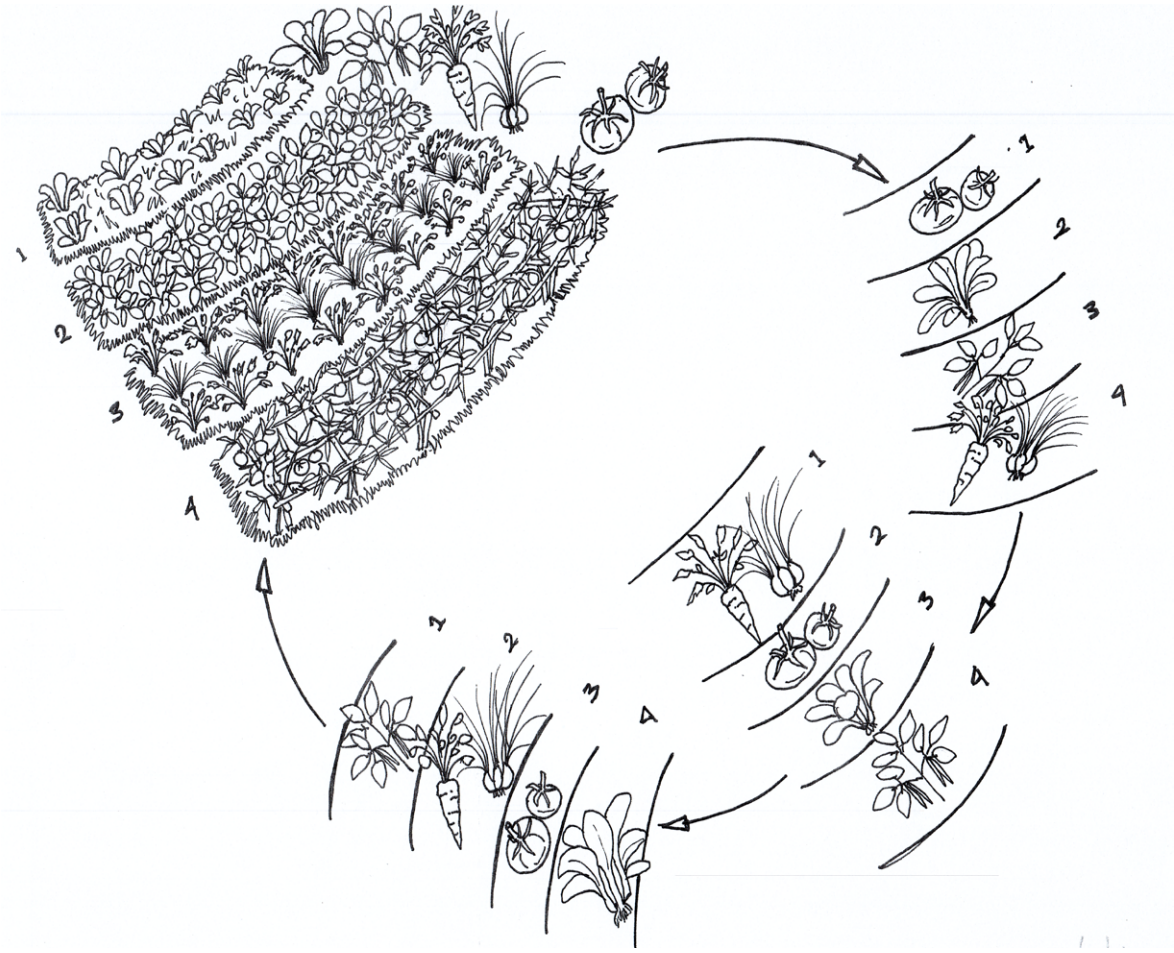
For example: rows of corn provide a physical barrier to protect plants growing between them.

Small legume trees are especially useful. Look at Family gardens (**Ch 10**), Trees (**Ch 15**) and Sustainable agriculture (**Ch 13**) for many examples and ideas or use your own. Market gardens are also affected in the same way, and you can reduce problems using the same techniques.

Using natural patterns instead of straight lines makes it easier to attract pest predators. They provide more edges and more diversity, and make it harder for pests to go from plant to plant.

CROP ROTATION

Crop rotation is very important for reducing disease and pest problems. Some pests and diseases live in the soil and cause a lot of damage if the same type of crop is grown on the same land over and over again. Changing crops causes diseases and pests to die out before the plant they attack is replanted.



An example is Brassicas (cabbage, cauliflower, broccoli, etc.). A fungus that attacks their roots lives in most soils and causes big problems if the plants are grown in the same place every year. This is because the fungus grows on the roots and increases every year. By rotating the crops, the fungi have nothing to eat and the numbers die back. Therefore, the problem is minimal. You can further reduce the problem by following the Brassica crop with Allium (onions, shallots) or grass (corn, wheat).

Occasionally very bad problems mean that you cannot grow a particular vegetable in a place for several years until the soil disease is completely gone. Consult with local soil experts if this is a problem for you. Remember that soil fungi are usually specific to a certain type or family of vegetable. In this situation, if you want to remove the disease as fast as possible, grow grass to rehabilitate the soil and nutrient stores, and help remove soil diseases. Apply micro-organism activators as well.

PLANT SPACING

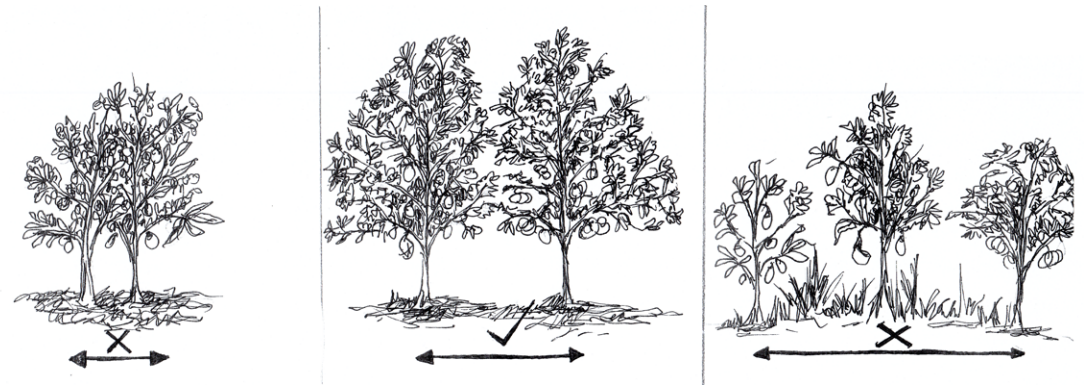
Correct plant spacing gives you maximum efficiency and production levels. It also allows the plants to be healthy and grow without constraint, which reduces stress and the chances of pest attack. The correct spacing is just enough area between the plants for them to grow to their maximum size.

When plants are too close they:

- Compete for water, nutrients and sunlight making them weaker.
- Are in constant leaf contact, which promotes fungal and bacterial problems.
- Do not have good air flow which also promotes fungal and bacterial problems.

When they are planted too far apart:

- Weeds grow quickly and compete for water, nutrients and sunlight.



CONTROLLING NEMATODES

Nematodes are microscopic worms that live in most soils. Some types of nematodes, in large numbers, can cause great damage to a plant's roots, causing the plant to die. A solution is to sow mustard seed as a green manure. Once you have harvested and cleared a crop, spread mustard seed over the surface of the bare soil, rake it in, water it, grow it until it is 45cm high and dig it in to the soil. If the soil is moist, the mustard decomposes, releasing chemicals known as isothiocyanates. These chemicals fumigate the soil so controlling the nematodes. While no garden is ever entirely free of these pests, this helps to control their numbers if they have become a problem. It also improves the soil for the next crop.

Identifying nematode problem | Planting mustard crop | Digging the mustard crop back into the soil

Another method for controlling nematodes is to use the remains left in a neem press from making neem oil. It is called neem seed cake and by adding it to your soil you will reduce the number of nematodes. A spray containing neem oil also works.

COMPANION PLANTING TECHNIQUES

Some plants grow very well together. Sometimes though, plants do not combine well and it results in slow growth and reduced production. This happens in family gardens, sustainable agriculture and among tree crops. Knowledge about plant companions helps to improve growth, increase natural pest and disease control, and allows higher production from your land. Some examples are given in Family gardens (**Ch 10)** and Sustainable agriculture (**Ch 13**).

Reasons for and examples of companion planting

Here are some specific objectives and the planting combinations to achieve them;

Kill root parasites/predators – Marigolds and crotalaria repel nematodes in the soil. Plant them throughout your vegetable garden to help reduce nematode numbers and add some colour!

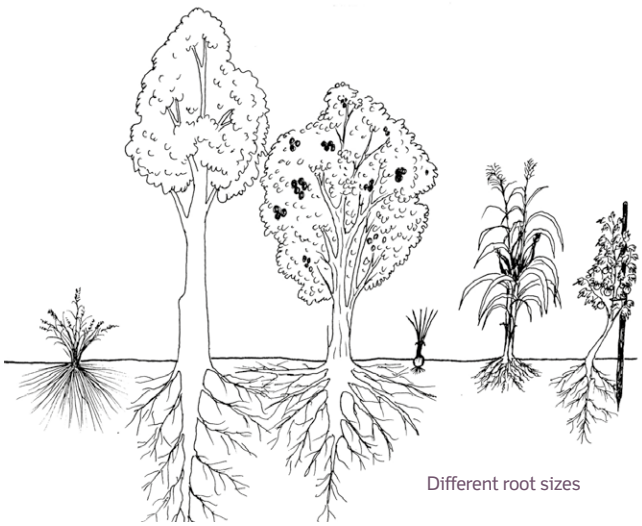
Repel insects – Plants and flowers which have strong smelling leaves or flowers confuse and repel pest insects that use smell to find the plants they want to eat: e.g. garlic, onions, marigolds, daisies, ginger, lemon grass. Tomato leaves repel some insects and reduce pest attack on eggplants.

Strong smelling lemongrass borders help deter pests

Attract predator insects and animals – Flowers help to attract predators to the garden. They are good to plant around vegetables, crops and even fruit trees, and look beautiful: e.g, dill, hibiscus, cosmos, zinnias, sunflowers, marigolds, legume shrubs, daisies and coriander. Roses are also good but they are usually the first plants attacked by aphids. They are, therefore, an indicator plant for potential aphid problems.

Slow down spread of pests – Planting different crops together slows pests spreading and reduces pest numbers. This is the same for family gardens, sustainable agriculture and trees.

Root growth – Different types of plants have different types of root growth. Knowledge of different root types allows you to grow plants and trees closer together. Some plants give out substances from their roots that make it hard for other plants to grow near them: e.g. eucalyptus, wormwood, and casuarina trees.



Different root sizes

SMART IDEA:

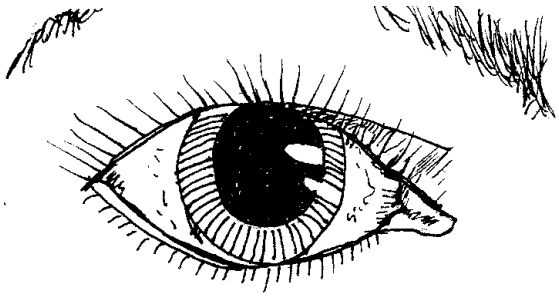
There is a lot of traditional knowledge in communities about plants that grow well together. This knowledge needs to be collected and shared so it is not forgotten and can be used into the future.

7. Preventative measures

Observation prevents many pest problems before they start.

General observations:

- Are the plants healthy and growing well?
- What is the soil condition and PH?
- Where do the seeds come from?



Pest observations :

- Where do the pests come from?
- Are pests attacking the plants?
- Are predators eating the pests?
- What types of pests are they?
- Are there homes close by for the pest predators?

Farmer looking for pest damage

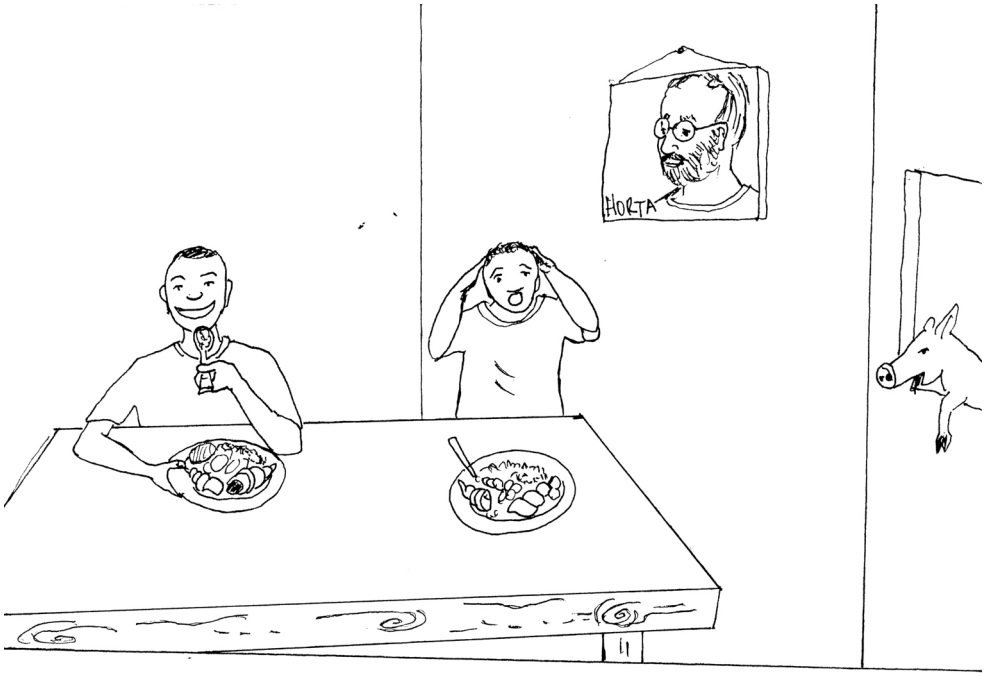
When you see pests and diseases early, management is much easier. Look for all stages of insect life: eggs, worms/grubs and adults (e.g. moth, fruit fly). Identification of the pest or disease is very important. If you do not know it, collect a sample to give to people who can tell you – farmers groups, government agriculture workers, NGO agriculture workers, etc.

Each plant has specific pests that attack it. Pests that attack one type of plant may not attack other plants nearby. This knowledge of which pests attack which plants improves techniques to prevent pest problems, such as crop rotation, companion planting and crop integration.

Also, different methods and sprays control different pests.

A specific control method or spray is much better than a general spray that kills many different insects. Where the pests come from is also very important: e.g. are the eggs in the ground? Are they laid by flying insects? And so on. This knowledge helps **a lot** to find and use the correct control technique.

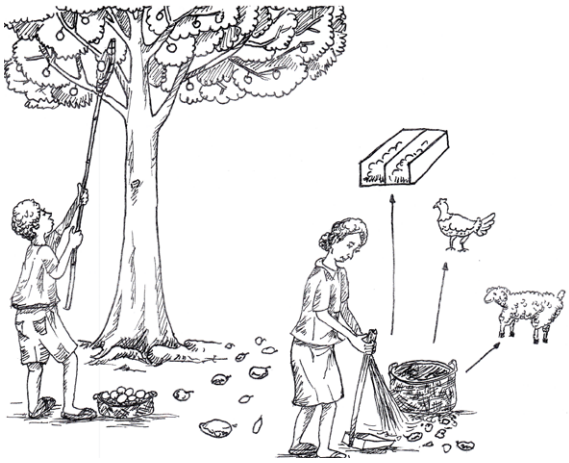
Women have a lot of knowledge as they do most of the weeding and maintenance, especially in home gardens. Observation of pest problems and control happens every day during other garden chores. They can teach children about the pest insects, good insects/pest predators and pest control. If you see a pest, removing it by hand is often the most effective pest control, especially for home and market gardens. Collect pest insects and feed them to chickens and ducks or kill them in a bucket of water. Cooked giant snails make excellent pig food and, in many countries, people also cook and eat them!



Eating snails

Pest insects also like to eat weeds. Through observation, find which weeds attract insect pests and grow them separately from your crops to attract the pests away. Once the weeds are infested remove them and feed them to animals, put them in liquid compost, or burn them. They are also your indicator plants to show when a pest is entering your garden.

GARDEN HYGIENE



Clean up any rotten fruit and feed it to animals or put it in your compost. Old fruit attracts and helps breed some pests.

Clean your tools after use. This helps to stop weed seeds and bad soil fungi/bacteria to spread.

Remove dead wood and plants which are infested with pests or fungi. Burn the old wood to stop problems from spreading.

Dust is harmful to plant growth and pest predators. Prevent excess dust by planting windbreaks, mulching and using ground-cover plants.

CUTTINGS, ROOT STOCK AND SEEDS

Make sure you take cuttings and root stock from plants that are healthy and disease free.

Good quality plant stock for cuttings

Diseased plant, not good for cuttings

The soil where the plants come from also needs to be free of bad soil bacteria and fungi. If not, you spread soil diseases which are often very difficult to remove once you have them. Check with the farmer about the crop and disease history.

Your seeds also need to come from disease- and pest-free plants to ensure you have good crops in the future.

PLANT DISEASES AND FUNGI

For above-ground fungal diseases: Trees suffering from fungi are helped by pruning some branches to let in more sun and wind. A fungus needs moisture to grow. Sun and wind help to keep the tree dry. Always remove dead wood from fruit trees to reduce the chances of fungi and diseases. Some vegetables can be trellised to reduce fungal risk.

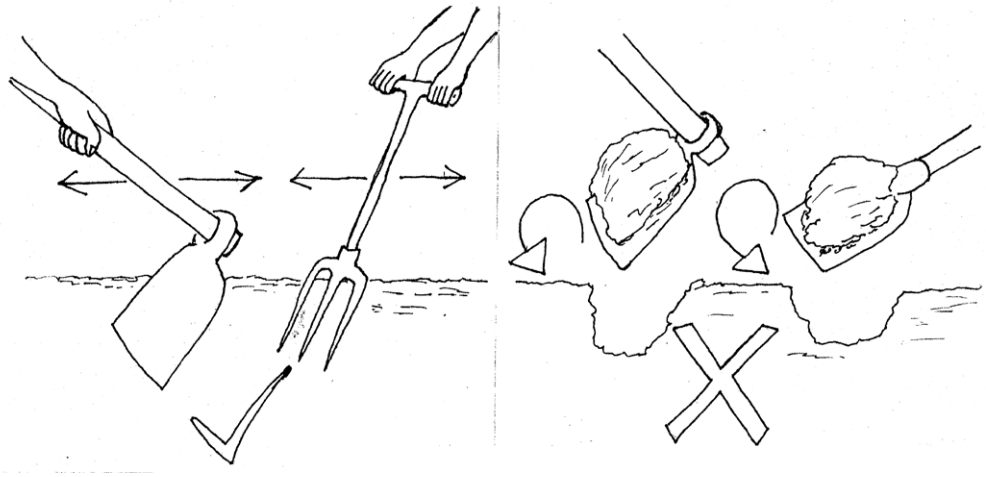
Good Hygiene: If a disease or a fungus is observed on a plant or tree, and does not respond to treatment, remove the diseased part and burn it to slow or stop the disease from spreading. For vegetables remove the whole plant affected. Do not put the infected plant material in the compost or use it as mulch. Closely observe other trees or plants for signs of disease. If the disease continues, other solutions may be needed.

Removing and burning branches with disease problems

Bamboo leaves in mulch or in compost help to reduce fungal disease. Bamboo leaves contain silica and, as they break down, the silica is taken up by the plants. Silica makes plants stronger and helps the water to move through the leaves and plant system more easily. This helps to prevent mould and other fungi from growing.

Some fungal diseases (sometimes called pathogens) live in the soil. You cannot remove them completely, but you can use good simple techniques to reduce and sometimes prevent the damage they cause:

- **Minimise digging:** Constantly digging the soil allows fungal diseases to multiply and disturbs the balance among soil insects, fungi, viruses, bacteria and other soil life. Only dig when you must; loosen the soil but do not turn it over. Build garden beds the right size so you do not need to step on them. These techniques reduce the danger of fungal disease.

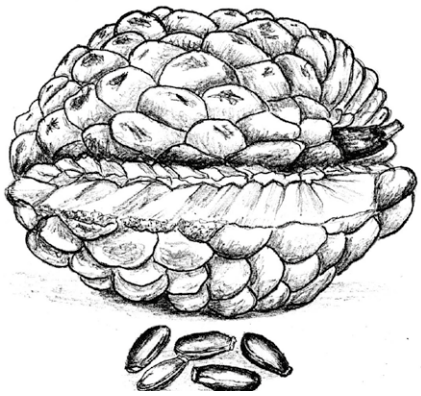


- **Healthy living soil:** Encourage a diverse population of good micro-organisms, which reduces disease by outcompeting pathogens for nutrients and by feeding on them too. Some micro-organisms even release antibiotics or chemicals that are harmful to fungal diseases (pathogens). Add organic matter to your soil through compost, mulch and green manure crops as well as micronutrient rich liquid compost, bacterial activators and biochar. Read Soils (**Ch 9**) for how to make and use these products.
- **Good drainage:** Promoting good drainage with raised beds and lots of compost and mulch minimises the wet soil conditions that many pathogens need.

PEST CONTROL FOR SEEDS AND SEEDLINGS

Custard (sugar) apple (*Annona squamosal*) seeds are traditionally used in Timor-Leste for protecting seeds, especially corn, when planting. Crush a handful of custard-apple seeds, and put the powder in water for three days until it ferments. Put your planting seeds into the water and leave them overnight before planting the next morning.

Sprinkle ash around the seedlings and on young leaves to help prevent fungi and insects.

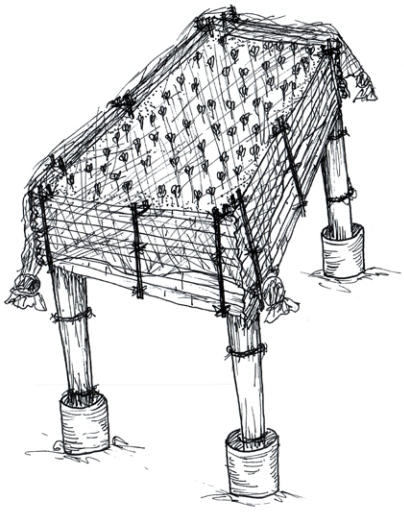


Many young seedlings are a favourite food of snails, slugs and other pests including rats and mice. Ants can also damage seedlings and remove seeds. When you grow the seedlings in a nursery it is much easier to stop these pests from eating your seedlings.

Methods:

- Use old mosquito nets to cover the seedling trays to prevent flying insects, rats and mice.
- If you use tables in your nursery, place the legs of the tables in containers of water to stop pests from climbing up. A thick band of grease (a hand's length) on the table legs also works.

A ring of grease around tree trunks stops pests from climbing up to eat the leaves or fruit.



This works for pests that lay their eggs in the soil each year, such as some caterpillars, worms and ants -which can spread disease, aphids and other pests. Trees that benefit include orange, mandarin, lime, pomelo, custard apple, soursop, mango and avocado.

Step 1: Place a 10cm wide band of material, thick plastic or tin foil around the tree trunk and tie it securely. Make sure the insects cannot get underneath.

Step 2: Cover the band with grease. Fold the top over to make it waterproof.

Step 3: Check every two weeks that the grease is still in place.

Beware: Do not put grease directly on the tree trunk, especially for young trees. The grease damages and may even kill them.

SMART IDEA:

Plant pumpkins under trees that suffer from sooty mould as a preventative measure.

Grease rings around tree trunks

MAKING AND USING BAITS AND TRAPS

Baits and traps are good ways to prevent pest numbers from building up and causing damage to your crops and trees.

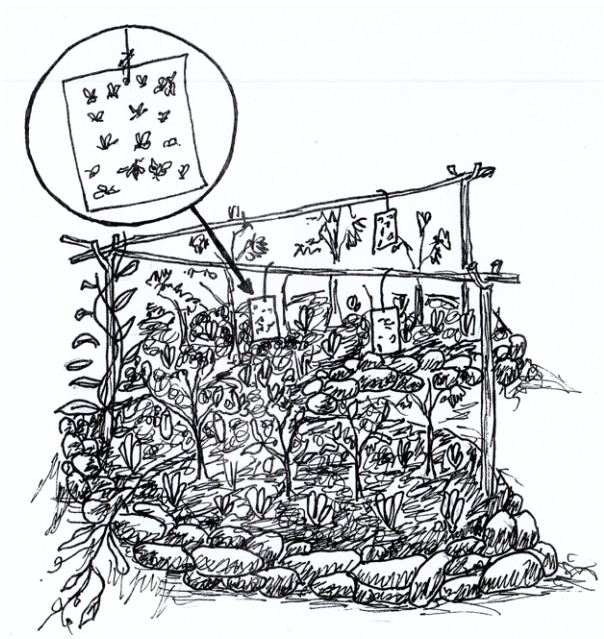
GENERAL PEST TRAP

Yellow painted cardboard coated with a sweet sticky substance (that does not dry), attracts and catches pests. This is because fruit fly and bugs like the sugary substance and, as they are also attracted to yellow, they get stuck to the cardboard.

It shows you which types of flying pests are present as well as reduces their numbers.

The sweet sticky substance (e.g. mashed banana or papaya) **must** be organic and natural as birds will come along and pick off the insects for food. This method also increases bird numbers, which are predators for insects.

However, if you start catching bees, this might not be the best trap to use.



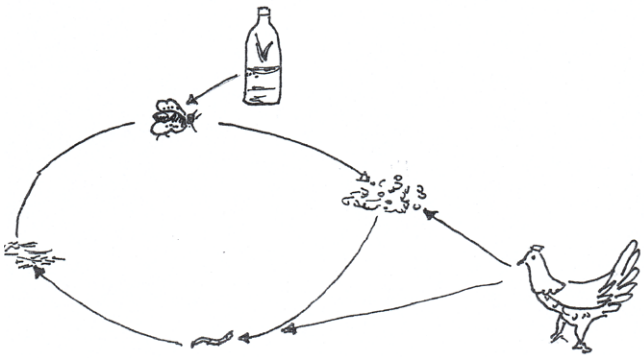
BAITS FOR FRUIT FLY

Fruit fly damage many different types of fruit, such as water apple, mango, guava, avocado, papaya, mandarin, oranges and many more.

A simple trap can be made using plastic water bottles:

1. Cut two 'V' shapes into the bottles half way down. Pull the 'V' out and bend the point down to prevent rain from entering.
2. Fill a quarter of the bottle with a liquid bait:
   a) Fermented fruit and water mixture (add a tiny bit of yeast too, if possible).
   b) Old beer mixed with water (stout beer is much more effective than lagers or ales).
3. Hang it upwind from the affected trees with string, strong grass or wire tied around the bottle neck. Ten bottles for each tree minimises fruit fly numbers.

Another method is to spray a strong neem mixture on the ground under the fruit trees and water it into the ground. Spray the mixture once before the fruit starts to grow and again before it starts to ripen. This stops the fruit fly from changing from larvae (small worms) into flies. Read the natural pesticides section later in this chapter for how to make a neem recipe.



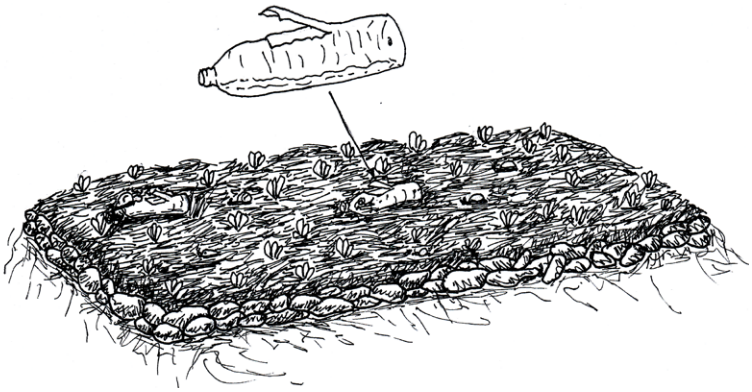
SMART IDEAS:

Put some turmeric in the baits to colour them yellow and aid the fermentation process. The yellow colour attracts more fruit fly.

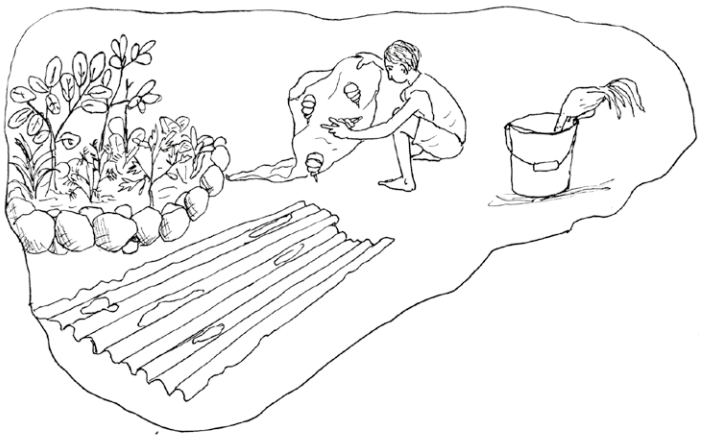
- Fruit fly traps work more successfully if your neighbours also use traps.
- Chickens under your fruit trees during fruiting season eat all the dropped fruit and heavily reduce next year's fruit fly population.

SNAIL AND SLUG TRAPS

Snail traps placed around the vegetable growing areas attract and kill snails. Cut a slit in the top of a plastic water bottle so it can open slightly. Lay it flat on the ground tucked in the mulch. Half fill it with a liquid bait of milk and water or beer. You can add small amounts of finely cut lettuce or cabbage. The snails and slugs enter the trap and get stuck in the water, unable to leave. Check the traps daily.

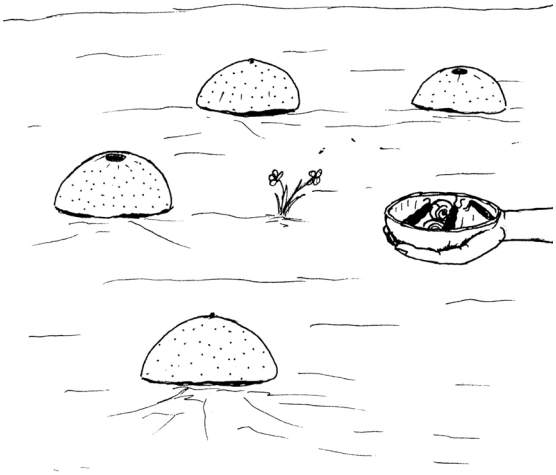


Place pieces of old tin roofing or wet sacks on the ground near your vegetable plots. Snails and slugs like to live underneath and are attracted to them. Check them every few days. Fresh coffee waste (husks) or fresh sawdust placed on paths around the vegetable plots helps to prevent snails and slugs from entering as they do not like the rough surface.



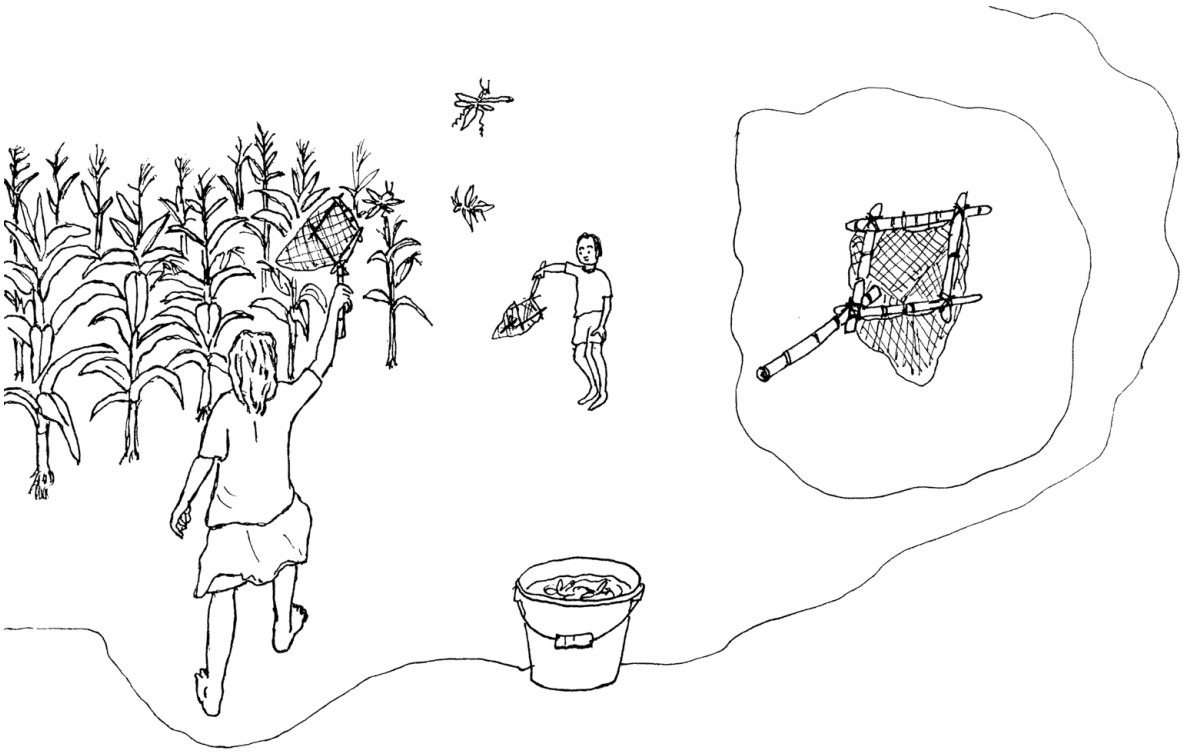
CITRUS SKIN TRAPS

Citrus fruit includes pomelo, grapefruit, orange and lemon. Place on the ground half the skins of fruit with a little bit of flesh still left. The skins attract pest insects, especially snails and slugs, which you can then feed to your happy chickens and ducks!



HAND NETS

Hand nets catch crickets and other flying and hopping insect pests. A simple frame of wood or bamboo with a net made from old fishing net or something similar works well. It is a fun game for children to see who can catch the most insects and reduces pest numbers quickly. However, they must be careful not to damage the crops!



SMART IDEA:

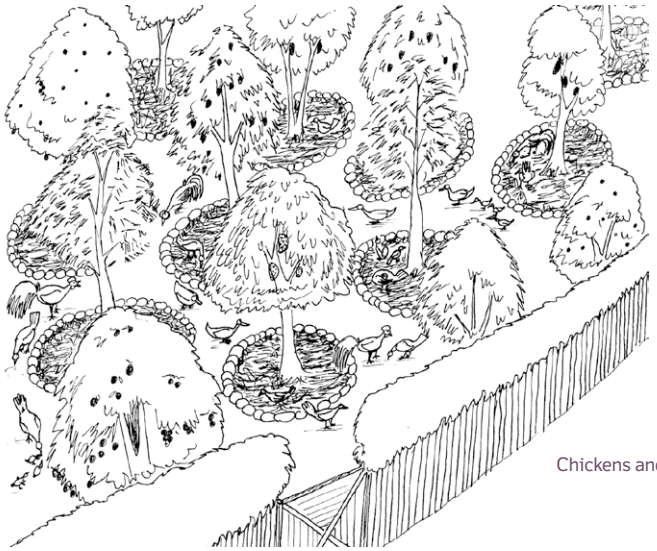
Feed all of the insects you catch to your chickens or ducks; they will be very grateful!

8. Using chickens and ducks for pest control

Chickens and ducks are very happy to do a lot of your pest control work for you!

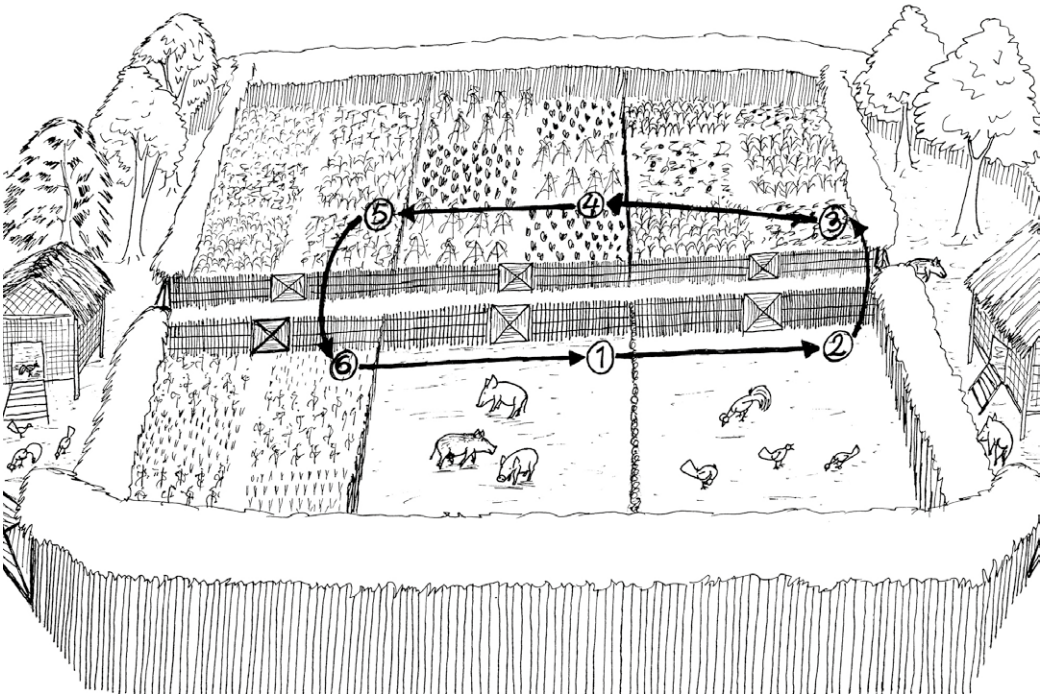
TECHNIQUES FOR PEST CONTROL:

1. Part of a fruit tree crop system – When you keep chickens or ducks in one area they clean under the trees, eating the larvae and insects on and in the ground that damage the trees. Your pest problem, therefore, becomes animal food. Chickens and ducks also clean up dropped fruit, greatly reducing fruit pest problems such as fruit fly.



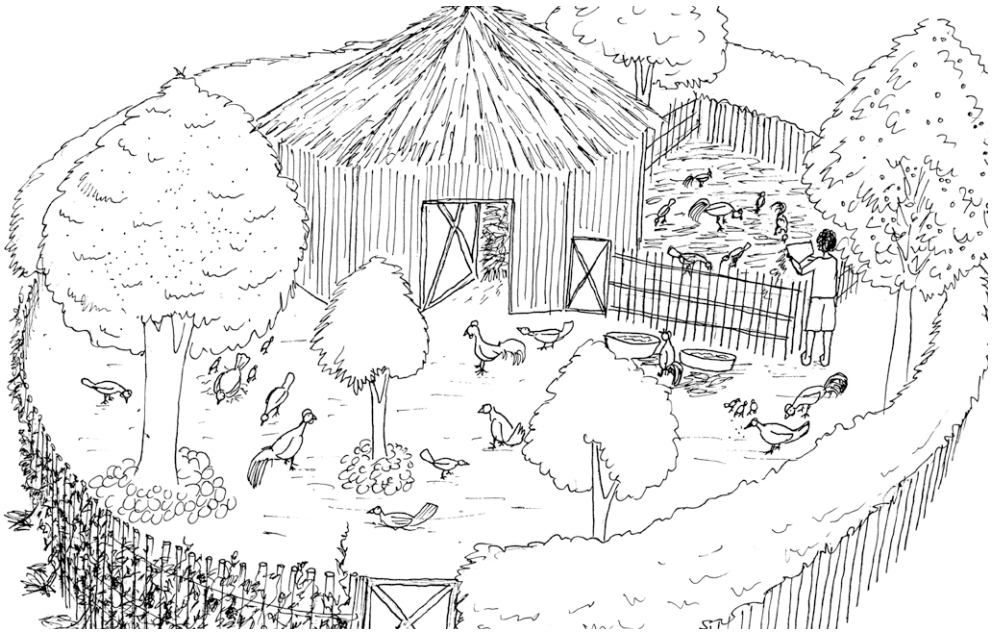
Chickens and ducks in fruit orchard

2. Part of a sustainable agriculture system – When you keep chickens or ducks on cropland after a crop has finished, they eat many pests in the ground that would eat the next crops: e.g. snails, insect eggs and larvae. At the same time the animals provide fertiliser for the next crops. This can be in a chicken or duck "tractor" or part of an animal/agriculture rotation system.



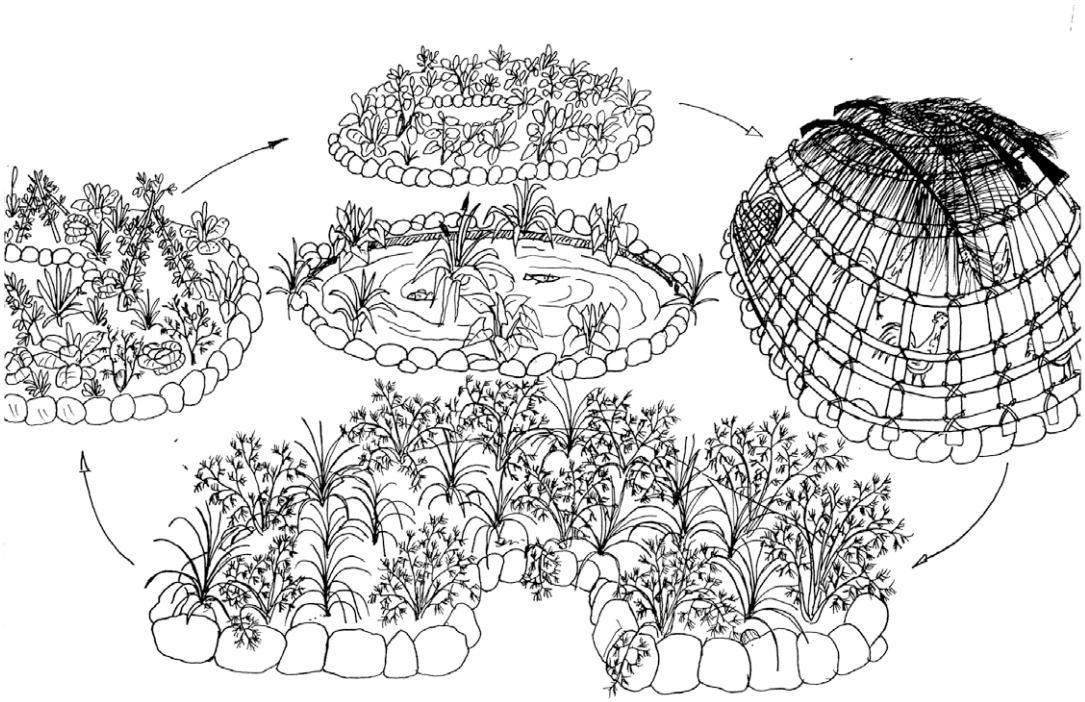
Chicken, pig and vegetable rotation system

3. Feeding insects to the animals – When you remove pest-infested plants and feed them to animals it provides high protein food as well as reducing insect numbers.



Feeding insects to chickens

Read the chicken and duck sections in Animals (**Ch 17**) for more details on making and maintaining animal systems.



Movable chicken house and vegetable system

9. Natural pesticides

Natural pesticides are a short-term solution to immediate problems.

Many of the natural pesticides do not kill the pests immediately but use deterrent methods or affect their reproductive systems. This makes them safer for beneficial insects and for the general environment.

DO NOT use natural pesticides if there are no pests and no crop damage.

Even a small amount of crop damage is alright. Take time to observe if pest predators are eating the pests and if the pests are spreading quickly or slowly. If you kill all the pests, it prevents predators from breeding and they take three weeks to breed up again. If you use a pesticide, leave a small section with pests so that some predators can still breed. They eat the pests you leave and more importantly they will remove future pest outbreaks too.

Some natural pesticides are very strong and kill all the insects, good and bad. Be careful because most insects do not harm your crops; killing them creates problems in the future.

Be careful when using all sprays: It is important to remember that many of the sprays listed here can also be harmful to you! You need to use protective clothing, wearing at least gloves and a mask, and make sure you especially avoid getting the sprays in your eyes.

SMART IDEA:

When you spray the plants, make sure you spray the backs of the leaves well as that is where insects hide and lay their eggs.

Recipes and techniques

HAND PICKING

Your hands are an excellent natural pesticide! You can control many pest problems by continual observation and removing pests by hand, so you do not need to make and use sprays!

NEEM SPRAY

The neem tree can be used to make a safe and effective natural pesticide spray. It comes from India but grows in many different tropical countries. Neem can be used on almost all insects, including mosquitoes. It works in different ways with different insects. Sometimes it can take a few weeks to show the effects because with some insects it breaks the breeding cycle, but with other pests, such as caterpillars, it can work almost immediately. It is one of the best plants to use because it is safe for people and it is not a problem for beneficial insects, especially pest predators. In some conditions it even increases beneficial earthworm production!

Target pests: Snails, nematodes, beetles, pest worms, moths, leaf miners, flies, grasshoppers, and more.

Methods:

- Crush the neem seeds and put them in a cloth bag. Place the bag in a bucket or drum of water overnight. Use 500grams of seeds for every 10litres of water. Use the liquid as a spray on the pest insects and affected plants. This method is more effective than using neem leaves.
- Take a large bucketful of fresh neem leaves, break them up and put them into a bucket of water. Leave it for two days, remove the leaves and use the liquid as a spray. (This is weaker than recipes with neem seeds in them.)
- Neem oil can be extracted by roasting and/or boiling the seeds. Then put the seeds in a bag, and either hand squeeze it or use an oil press. Another method is to soak crushed seeds in alcohol (ethanol). These methods take more time or are more costly but produce a much stronger product.

Important: use the neem seeds within three months of collecting them or there will be no oil left.

There are many traditional recipes for using neem. Ask elders in your region and look in the reference chapter for where to find more information about producing and using neem products.

COMMUNITY IDEAS:

Neem is so useful in so many ways, but it can become a problem weed. If it already grows in your area, a community neem oil extraction cooperative is an opportunity to supply and use the valuable oil and make some income too. The oil is much easier to use than trying to extract it continually from leaves, seeds and fruit.

CRUSHED INSECT SPRAYS

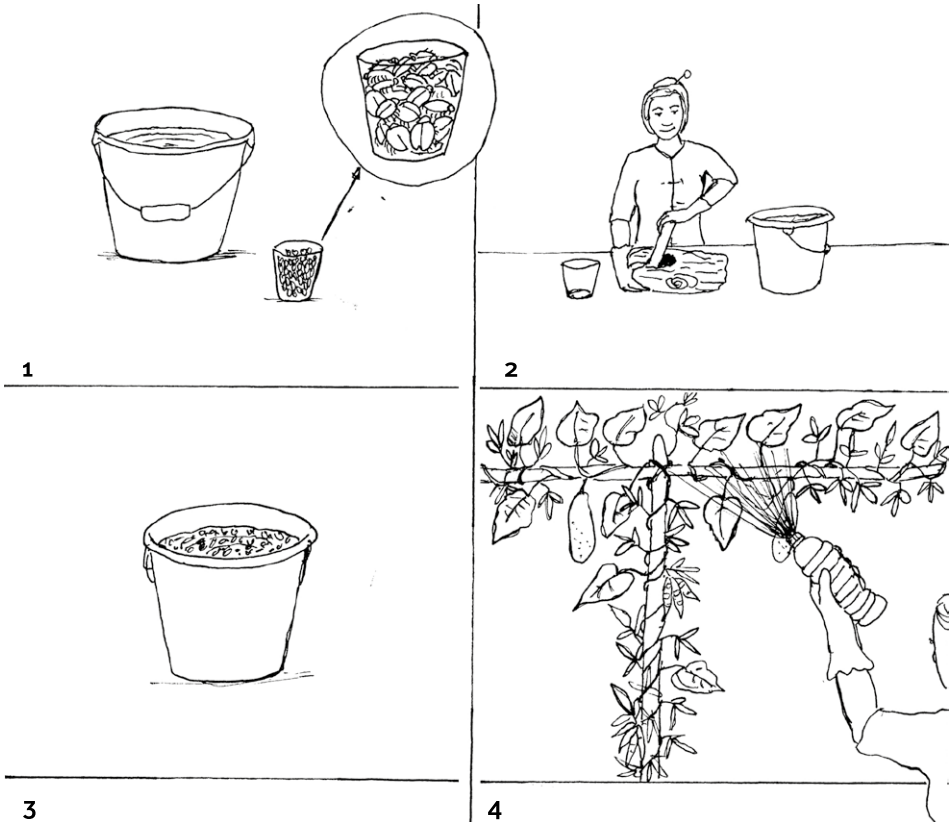
Making sprays out of the insect pests themselves is a simple and effective pest control!

Target pests: Caterpillars, slugs, snails and various insects including grasshoppers.

Method: Take a handful of the insect pests that are eating your plants, crush and mix them in a small bucket of water. Add a teaspoon of sugar and a teaspoon of powdered milk to help it ferment.

Leave it for two days. Strain the liquid and spray the affected crops.

Pests that are the same as the pests in the spray are repelled. The remaining insect bodies can be put in containers and placed around the crops. The smell continues to repel the pests.



GLIRICIDIA SEPIUM LEAF SPRAY

Gliricidia sepium, known as gliricidia, is a very common plant throughout the tropics used for animal fodder, nitrogen fixing, living fences and rat poison, and it is also a useful pesticide!

Target pests: worms, weevils, caterpillars.

Method: Collect 500g of fresh gliricidia leaves.

Crush the leaves and mix them with 2 litres of water, then add another 3 litres of water.

Leave it for a day. Strain the liquid to remove all the leaves.

To use the spray mix 500ml of the gliricidia pesticide with 10 of litres water and spray it on the pest-affected plants.

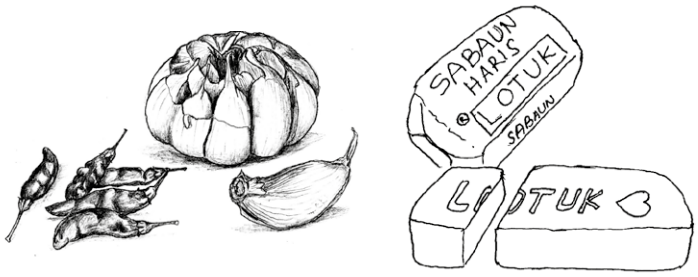
SOAP SPRAY

For this recipe and all others that include soap use natural soap. The active ingredient for effective pesticide use comes from the fatty acids in animal fat, coconut oil or vegetable oil. Do not use detergents (which are not actually soaps), dish soaps, or any products with chemicals.

Target pests: Natural soap makes an effective pesticide for aphids, mealy bugs, caterpillars, and other leaf-eating insects.

Method: Use a large spoon of soap or liquid soap per 1 litre of water. Spray only on the pests and damaged plants.

CHILLI/GARLIC/SOAP SPRAY



Garlic is a pesticide, fungicide and repellent, and chilli is a pesticide and repellent. The soap helps the spray to stick to the plants and insects and also works as a pesticide.

Target pests: Use for aphids, worms, caterpillars and moths.

Method:

1. Cut up three bulbs of garlic with a large handful of chillis and put them in a 2 litre pot of water. Bring it to the boil then add 4 tablespoons of natural soap. Stir it well and leave it for a day.
2. Strain the liquid, and mix two cups of the liquid with 10 litres of water to use.

WHITE OIL SPRAY

Easy to make and use, white oil spray has been used effectively for hundreds of years. The oil coats the pests and the soap helps the oil to stick to them. The water is needed to make sure the liquid can be sprayed.

Target pests: aphids, scale, mealy bug and citrus leaf miner as well as caterpillars.

Ingredients:

- Half a cup of vegetable oil.
- A cup of water.
- A tablespoon of natural soapflakes – grated from a bar of soap.

Method: Stir the ingredients well in a bowl. Pour them into a spray bottle, and spray the affected plants. Always spray in the late afternoon because in the daytime the oil can magnify the sun and burn the leaves.

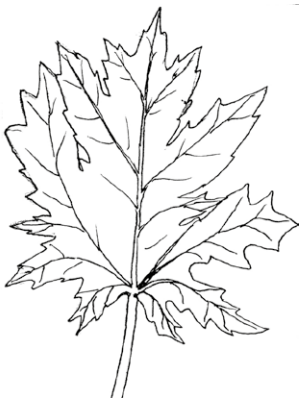
Caution: Do not spray on soft-leaf plants, such as lettuce, as it can burn them.

SMART IDEAS:

Garlic and chilli plants naturally repel many insects. Plant them around fruit trees and other vegetable crops to reduce insect problems.

- Garlic and chilli can also be used separately as sprays.
- If this recipe does not work well, try making a stronger pesticide by mixing the liquid with only 5 litres of water.

PAPAYA SPRAY



Papaya leaves, seeds and the unripe fruit can be used to repel pests, including rodents, and contain insecticides and fungicides.

Target pests: Papaya spray can be used for aphids, termites, bugs and caterpillars. It is also effective on powdery mildew and coffee rust.

Method: Collect a kg of papaya leaves (about one big plastic bag full). Cut them finely and add them to a litre of water. Mix it well and leave it for an hour. Remove the leaves and add another 4 litres of water and a large spoon of soap. Spray it onto the insects.

For termites: crush young unripe papaya fruit and collect the juice. Spray the liquid directly onto the termites and damaged wood.

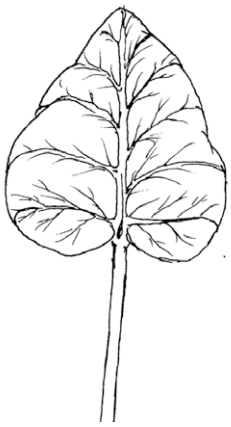
GINGER JUICE SPRAY

The ginger root is effective as a repellent and insecticide for a range of pests. It is also good in combination with garlic, chilli and/or soap.

Target pests: Spray it onto the damaged plants to control the larvae of worms and caterpillars.

Method: Finely grate a small handful of ginger root into a bucket of water. Leave it for a day.

TARO LEAF SPRAY



Taro leaves contain oxalic acid. When insects eat them it feels like eating broken glass as the oxalic acid is in the form of needle-like crystals! The oxalic acid can cause some people to develop itchy skin so it is better to wear gloves when preparing and using the pesticide.

Target pests: Leaf-eating insects.

Method: Crush 10 taro leaves and put them into 5 litres of water (about half a bucket). Mix it well. Splash the liquid onto the crops using a branch of leaves. Make sure each plant is well covered to give it good protection.

TOMATO LEAF SPRAY

Tomato leaves contain a natural pesticide, a repellent for pests and a mild fungicide. The pesticide also attracts pest predators, such as ladybirds.

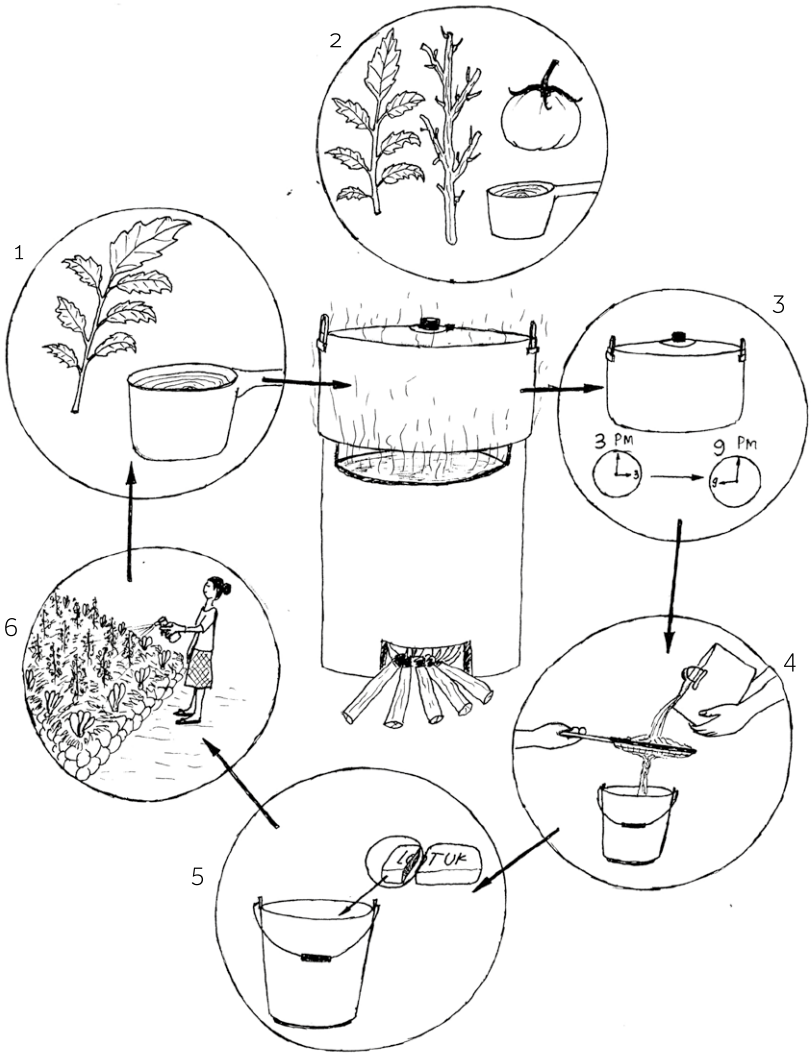
Target pests/diseases: It can be used on aphids, ants, worms, caterpillars, insect eggs, grasshoppers, some moths, nematodes, whitefly, fungi and bacterial rot.

Methods:

A simple recipe is to add one cup of chopped leaves to two cups of water, leave it for one day then strain and use.

A stronger recipe is:

1. Gently cook 1kg of leaves in 2 litres of water for 30 minutes.
2. Finely cut two handfuls of leaves, stem and green fruit and add to 2 litres of water.
3. Mix them together and leave it for six hours (or half a day).
4. Strain the solids from the liquid.
5. Add two tablespoons of natural soap.
6. Spray every two days on target insects, especially moths, which are in large numbers.



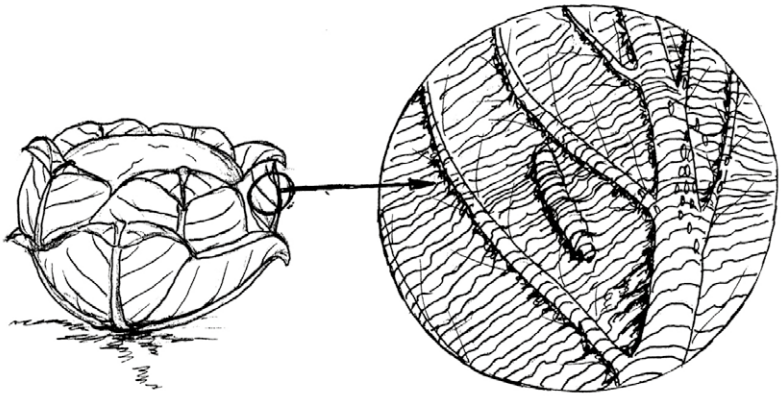
WARNING: Tomato leaves when used as a pesticide are poisonous for humans. This is because the chemicals in the leaves become much more concentrated. Wear gloves and protect your nose and mouth with a mask at all times.

GLUE SPRAY

A glue spray sticks to small insects and suffocates them. It is made from the water left over from cooking cassava, taro or potatoes.

Target pests: It is useful for aphids, caterpillars and whitefly but try it on other small insects as well.

Method: Mix some of the cooking water with fresh water to make a mixture. The strength varies depending on the type of vegetable you have just cooked. A good mixture leaves a thin coating on the plant when the mixture is dry.



Glue spray covering a caterpillar

PYRETHRUM SPRAY

Pyrethrum is obtained from the dried seed cases of the daisy plant, Tanacetum cinerariifolium, which grows well in high altitude tropical areas and in the dry season in other tropical areas. The active components of pyrethrum are the pyrethrins, which attack the nervous systems of insects. The insecticide decomposes in contact with sunlight.

Target pests: Aphids, army worms, cucumber beetles, cutworms, squash bugs, whitefly, leafhoppers, thrips and Colorado potato beetles.

WARNING: Pyrethrum is a very strong spray that kills good insects including bees. Only use it when other sprays have not worked and **only** spray directly on the target pests. Wear protective gloves and a mask when making and using it.

Methods:

- A tablespoon of fresh flower heads (about three or four).
- A litre of boiling water.
- Half a teaspoon of natural soap powder.

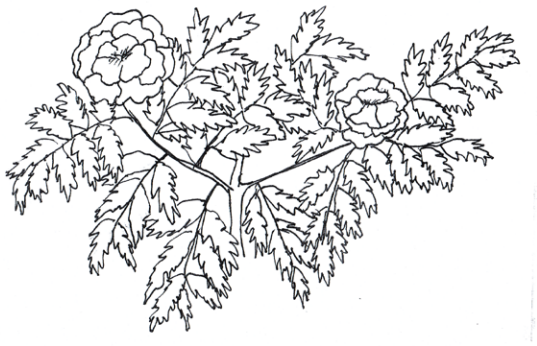
Pour the boiling water over the flower heads in a bowl. Leave it for an hour. Remove the flowers, add the natural soap and stir it until it is dissolved. Pour the liquid into a spray bottle and use it on pests.

OR

Pick the flowers in full bloom and hang them in a dark sheltered spot to dry. Drying the flowers increases the pyrethrin levels. Once they are dry, crush the flowers into a powder.

Soak ten grams (approximately two tablespoons) of pyrethrum powder into three litres of warm water for three hours. Add three teaspoons of natural soap or vegetable oil. Mix the ingredients. Put the liquid into a spray bottle, and spray.

MARIGOLD SPRAY



The scented varieties of marigolds drive away pest insects and contain compounds that are poisonous to some types of root-eating nematodes. They also attract beneficial insects such as ladybirds and parasitic wasps.

Target pests: Repels asparagus beetles, tomato hornworms, leaf cutting and chewing insects.

Method: Mash a cup of marigold leaves and flowers. Mix it with 500ml of water. Let it soak for 24 hours. Strain the liquid through a strainer or cloth. Dilute it further with 1.5 litres of water then add a quarter of a teaspoon of natural soap. Spray the target pests.

WOOD ASH

Wood ash (uncontaminated by chemicals from plastic, etc.) is effective in repelling pests when it is sprinkled both on the plants and on the ground around them. Different types of wood ash can repel different pests: e.g. eucalyptus ash is good to control slugs and snails, while putting ash from a burnt corn cob around young bean stems keeps ants away.

Target pests: Ash will dehydrate soft bodied insects such as caterpillars, cutworms, weevils, aphids, snails and slugs.

Method: Spread the ash evenly on the leaves and target pests, and for cutworm spread it over the ground around the plants. The ash also prevents moths and flies from laying eggs in the ground close to the stems.

CITRUS-SKIN SPRAY

Citrus skin contains naturally occurring pesticide compounds called limonene and linalool. They act on the sensory nerves of insects causing over-stimulation, which results in paralysis and death.

Target pests: To control soft bodied pests such as aphids and mealy bugs and as an ant repellant.

Method: Pour a litre of boiling water over the skin of two oranges. Leave it for 24 hours. Strain the mixture into a container and toss the peels into the compost. Add one teaspoon of natural soap, mix, and spray it on the target insects or, if they are ants, on their nests. It smells nice too!

LIME-POWDER SPRAY

There are several different types of lime powder to use against pests as it is a natural fungicide and pesticide. Agricultural lime is a mild animal friendly product which can be used directly on plants without burning them. Hydrated lime – or calcium hydroxide – is corrosive and is not recommended.

SMART IDEA:

Lime powder can be added to other natural pesticides to create a general pest control spray.

Target pests: This spray is especially effective against spider mites, useful on other pests too.

Method: Add a quarter of a cup of agricultural lime to 4 litres of water. Mix in three tablespoons of natural soap. Stir the solution and pour it into a spray bottle. Spray a leaf of the infected plant with the solution and wait a few days to see if there is any damage. If there is not, spray the infected areas of the plants, targeting the visible insects. Reapply the insecticide after rain or windy weather.

Careful:

- Lime-powder spray can harm or kill plants from the Cucurbitaceae family – pumpkins, gourds, cucumbers, zucchinis, luffas, melons, etc. Do not use it on them.
- If you overuse lime pesticide, it increases your soil PH level. This can cause problems for plant growth. Check your soil PH levels regularly. Read Soils (**Ch 9**) about soil pH.
- Take care when using lime-based sprays; wear protective gloves and a mask.

CUSTARD APPLE (ANNONA SQUAMOSA) SPRAY

The custard (or sugar) apple tree – *Annona squamosa* – has insecticide and repellent properties. Compounds in the plant material prevent insects from feeding, so they starve. You can use the leaves, roots, seeds and fruit to repel pests.

Target pests: Stem borers, leafhoppers, caterpillars, beetles, cotton boll worms, aphids, moths.

Method: Collect two handfuls of seeds and dry them. Grind them into a fine powder. Mix the powder with 4 litres of water and soak it overnight. Spray it on the target pests. The quantities in this recipe may need adjusting depending on the success rate.

TOBACCO LEAF SPRAY

WARNING: Tobacco spray is not recommended unless it is used as a last option on a severe pest problem. Wear gloves and a mask to protect your hands and face when making and using tobacco spray. It is very poisonous and it kills many useful insects as well.

Target pests/diseases: Use on aphids, slugs, snails, caterpillars and the leaf-curl virus.

Method:

Soak a kg (a plastic bag) of crushed leaves in 15 litres of water for a day and a night. Add two big spoons of natural soap and mix it well. Remove the leaves then use it as a spray.

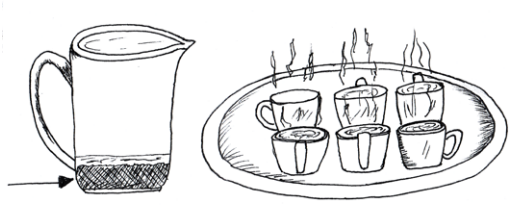
Dry the leaves and grind them into a powder. Use the powder directly on pests.

OR

Tobacco leaves ground into dust and sprinkled on the soil around the plants you want to protect keep away leaf-eating insects. The dust can be made into a tobacco tea and sprayed onto plants; the nicotine in tobacco is toxic to pests.

Careful: Do not use tobacco spray on tomato, potato, eggplant, capsicum or chilli plants or roses as it damages them.

COFFEE (USED GROUNDS/POWDER)



Used coffee grounds and powder are great for pest control. Ants especially do not like them, and it also works against snails, slugs and other insects. Simply spread the used grounds/powder around plants you want to protect or where those pests are a problem.

BETEL NUT JUICE

Saliva containing betel nut is an effective poison for giant snails, other snails and slugs!

Target pests: snails and slugs.

Method: Collect the saliva from people chewing betel nut in a bucket, mix it with water and spray it directly on snails. It could be the betel nut, or the lime powder, or a combination of both, but it works! Spray it on the outside of your vegetable plots to deter the snails from entering. However, it is NOT recommended to spray it directly onto plants. Reapply regularly.

BETEL LEAF SPRAY

Target pests: snails, slugs, soft bodied insects.

Method: Boil two litres of water, add ten leaves and simmer for 15 minutes. Remove it from the heat, add a tablespoon of natural soap then leave it to cool. Spray the liquid onto the affected plants and the soil for snails and slugs.

TRADITIONAL SPRAYS

Many communities have knowledge of traditional natural pesticides which can be combined to make effective sprays.

Be careful because some traditional plants are very strong; they can kill many non-pest insects and even birds and small animals if they are not used correctly. For every ingredient, research its properties and how much to use, either on the internet or by checking with government and NGO agricultural workers. **Always** wear gloves and face protection when making and spraying the natural pesticides. Many of the leaves and plant materials can cause skin problems, are poisonous and cause sickness after prolonged direct contact.

Examples of natural pesticides which are very strong and **not** recommended – such as rotenoids – are found in plants from the Derris family, a strong legume vine, and tobacco. Derris roots, in particular, kill many beneficial insects and can be toxic to people, birds, fish and animals.

Each community has its own knowledge of medicinal and poisonous plants. Apply this knowledge and experiment on a small area first before using the sprays on a whole crop or garden.

TRADITIONAL RITUAL PEST REMOVAL

Traditional pest removal occurs in many tropical countries when pest problems are large and when nothing else has worked. It usually involves catching and using the pest in a ceremony. It is not encouraged when the ritual treats the pest cruelly.

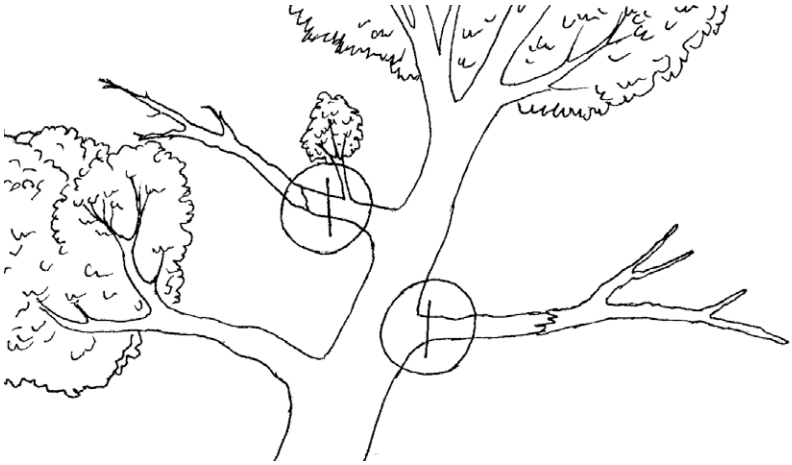
Natural fungicides

WHAT IS A FUNGUS?

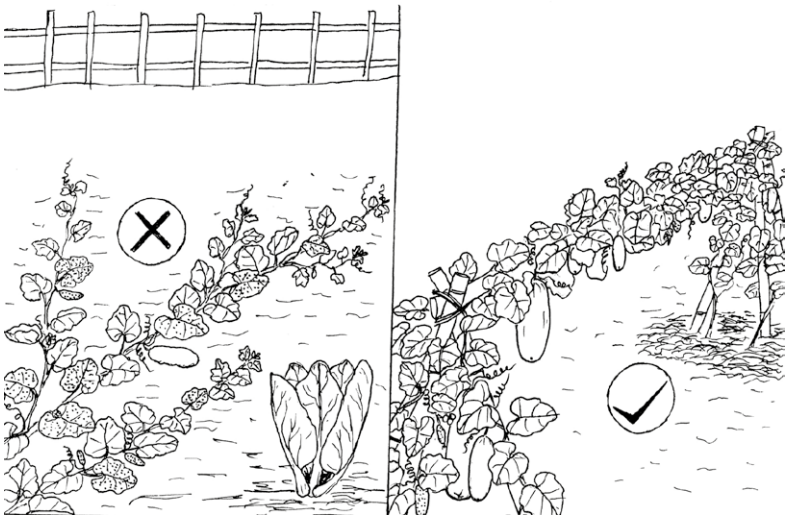
A fungus is an organism different to plants and animals. It does not photosynthesise as plants do; it absorbs its food from its environment. Fungi live more successfully in wet or moist conditions in and on the surface of plants, animals, wood, people and even cement and other non-living surfaces.

Fungi can cause problems for plants by covering surfaces, rotting and preventing normal growth, and sometimes allowing bacteria to damage the plants too. The most important step for controlling fungi is to promote gentle winds, sunlight and air flow. Fungi like dark, damp conditions and rotting materials.

To protect trees from fungal infestation, remove all dead wood and prune the trees to allow enough wind and light through. Only prune as much as is needed.



For vegetables, remove old and dead leaves and provide trellising for climbing plants such as peas, beans and tomatoes. Any badly diseased plants should be removed and burned.



Do not let mulch touch the trunks of trees or stems of vegetables.

However, REMEMBER that most bacteria and fungi are actually harmless or beneficial to plants. We need them in the garden and in the soil to maintain good production; only use natural fungicides directly on specific problems.

NEEM SPRAY

You can also use neem as a fungicide. Make a recipe from neem seeds similar to a natural pesticide (as outlined above) and spray it on powdery mildew and rust mildew. It may work on other fungi as well but research is not yet complete. Experiment with neem yourself!

SEAWEED TEA

Collect some fresh seaweed, rinse it in water to remove some of the salt, and put it into a bucket of water. Leave it for two weeks. Strain the liquid, use the seaweed as mulch, and spray the liquid on the affected plants.

BETEL LEAF AND CLOVES

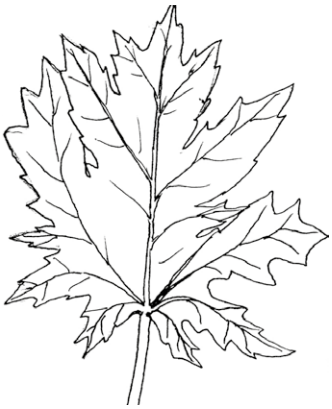
Boil two litres of water, add ten betel leaves and 20 cloves, and simmer for 15 minutes. Remove it from the heat and leave it to cool. Spray it on the affected plants.

GARLIC

Dry two bulbs of garlic and crush them into a powder. Mix a big spoon of garlic powder with 1 litre of water and spray it on mildews and tomato and bean fungi.

PAPAYA

The papaya insecticide spray (on page 41) can also be used as a mild fungicide for coffee rust, powdery mildew, and rice brown leaf spot.



COFFEE (USED GROUNDS/POWDER)

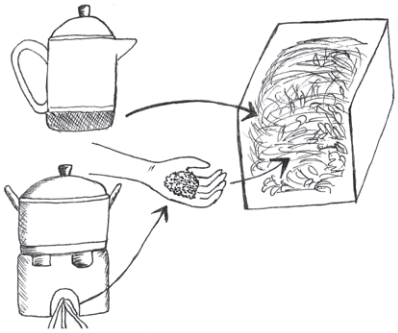
When coffee grounds break down in the soil they create their own fungi and moulds which outcompete other fungal colonies. The natural mould and fungi colonies on coffee can suppress some common soil fungal rots and wilts including the Fusarium, Pythium, and Sclerotinia species.

DILUTED URINE

Dilute one part urine to four parts water and spray it directly onto plants affected by mildew (a powdery residue caused by fungi).

SMART IDEAS

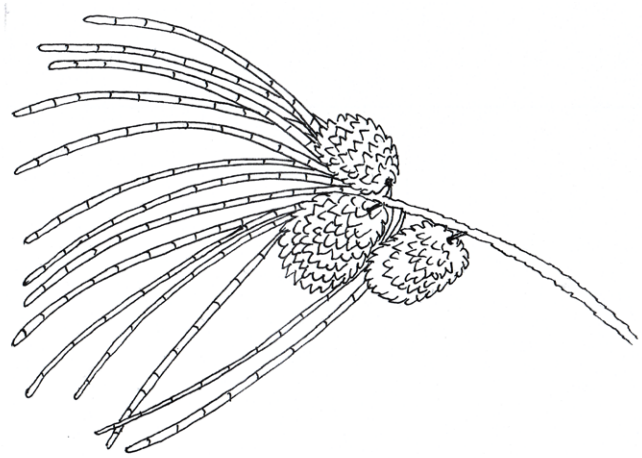
- Rinse the coffee grounds with water first to reduce the acidity.
- Add the grounds into your compost to help prevent a build-up of problem soil fungi, but rinse them in water or add ash because coffee is acidic.
- Throw a handful of used grounds/powder into the hole before you plant tomatoes, capsicums or eggplants, because these plants can suffer from soil fungal (wilt) problems.



BURNT BONE ASH (FOR PHYTOPHTHORA AND OTHER ROOT FUNGI)

Soak a handful of ash from burnt animal bones in 5 litres of water. Stir it for at least five minutes then leave for at least three hours. Dilute one part of the liquid to ten parts water and pour it over the soil around the leaf edge (root feeding zone) of the susceptible plants.

CASUARINA



Casuarina is a common tree from India which grows throughout Southeast Asia and into the Pacific Islands. Casuarina leaves are very useful for treating mildew and other fungi, especially powdery mildew, as well as stimulating the growth of strong plant stalks.

1. Collect a big saucepan full of casuarina needles (leaves).
2. Fill it with water, cover the saucepan with a lid, bring it to the boil and simmer for 20 mins.
3. Cool and strain the contents, leaving a liquid concentrate.
4. If you are using it immediately, mix it 50:50 with water and spray directly onto the mildew or fungi.
5. If you are storing it, leave it for two weeks in cool place and it **increases** in strength over time. Mix it 1:9 with water (e.g. 100ml Casuarina liquid to 900ml water) and spray it directly onto the mildew or fungi..
6. Use the spray weekly until the disease is gone.

MILK

Milk (fresh, old or even powdered) helps to prevent powdery mildew and other leaf-surface fungi. Mix one part milk to ten parts water and spray it on the plants once a week. It can also be used to help treat powdery mildew, but it works best as a preventative measure.

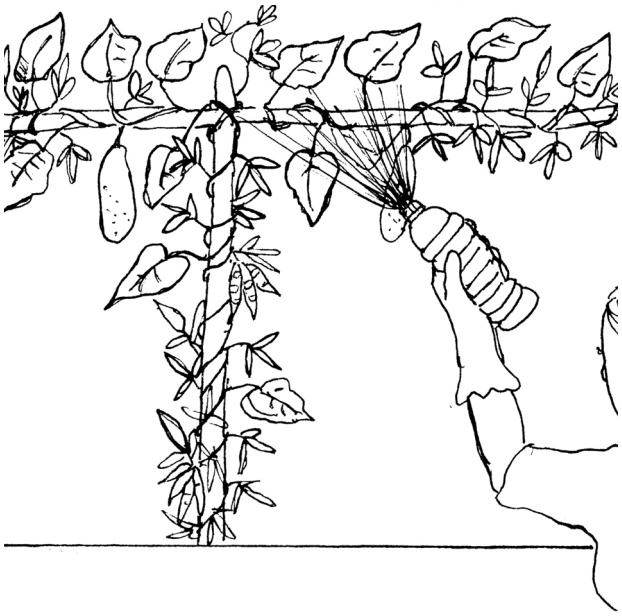
Herbicides

There are sections on natural weed control, including organic herbicides, in Family Gardens (**Ch 10**) and Sustainable Agriculture (**Ch 13**).

How to apply natural pesticides and fungicides

To apply the pesticides and fungicides outlined in this chapter you can use a hand-made bamboo sprayer. How to make one is explained later in this chapter; it is more effective than a broom or branch.

For family gardens and small pest problems an effective method is to use a plastic hand sprayer. An plastic water bottle with very small holes in the lid also makes a very easy and cheap sprayer.



The most effective way to spray is using a spray pack, but these are expensive and require maintenance. A group can buy one or have one as part of a community tool bank.

Bamboo sprayers, spray packs and plastic hand sprayers MUST be cleaned with water after every use.

If you are using a sprayer bottle or spray pack, you **must** spray under the leaves too. Most pest eggs and pests eat from underneath the leaves; if you spray the top only, you do not kill them all.

Always wear long pants, a long shirt, gloves, shoes and a cloth over your nose and mouth when making and using natural pesticides. Glasses to protect your eyes are also important. Some natural pesticides can cause skin problems and make you sick if you get too much on your skin or in your mouth, nose or eyes.

- A traditional method to apply the liquid treatments is a broom or a tree branch; however it is not very efficient:
- The natural pesticide or fungicide is not spread evenly.
- There is more chance of getting it on your skin.
- Beneficial insects are more likely to be negatively affected.
- It is hard to get underneath the leaves where many insects, eggs and fungi are found.
- It is wasteful.

STORAGE

Natural pesticides last a week or two if they are kept in a cool place and a month or more when kept in a refrigerator. Label them well! Keep them away from children and tell everyone what they are and not to touch. Only make the sprays when you need them but make enough for follow-up sprays in case they are needed.

"Stop! Thats natural pesticide, not juice! We need better labels."

SMART IDEAS FOR ALL NATURAL PESTICIDES and FUNGICIDES:

- Stop using the sprays at least two weeks before harvesting. This is **very important**! It prevents food from containing pesticides that can also make people sick.
- Do not use sprays on seedlings and young plants unless it is absolutely necessary.
- Rotate the sprays to stop the insects becoming resistant to one type of natural pesticide.
- Some sprays work better than others. Experiment for yourself.
- Only spray late in the afternoon to prevent the leaves from burning in the hot sun.
- Do not spray in moderate or strong winds.
- In the wet season spray at least three hours before any rain so the spray can work properly.

MONITORING RESULTS

Results of applying any natural pesticide must be continuously observed.

- How well has it worked?
- Does the plant need to be resprayed?

Often sprays need to be used two or three times over a few weeks to be effective. If the pest problem is not stopped, you have a number of choices:

- Respray.
- Try a different pesticide.
- Try a stronger mix.
- Mix different natural pesticides together.

Assess the situation for other factors and solutions.

Monitoring crops after spraying

MAKE A SPRAYER FROM BAMBOO

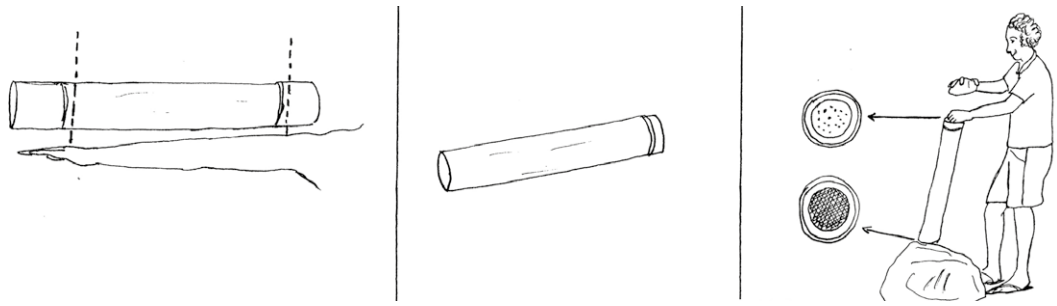
Information here was taken from Liklik Buk, a development book compiled by Liklik Buk information center, Lae, Papua New Guinea.

Materials:

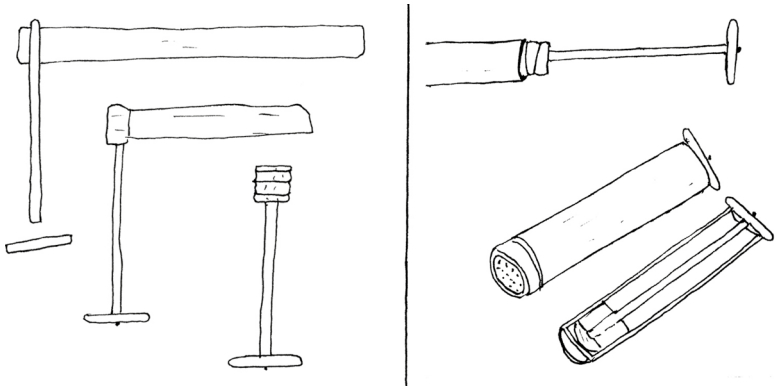
- A bamboo tube an adult arm length long between nodes, and 3 to 4cm wide.
- A wooden rod, about 1m long; make sure it is longer than the bamboo so it can fit inside it. A hard wood is best.
- Nails for making holes.
- A hammer.
- A saw.
- A strip of cloth, about 1m long and a finger length wide.
- Small length of wire or strong grass.

Method

1. Cut the bamboo tube so that one end has the node closed and the other end is open. There cannot be any other nodes between the ends. Use the hammer and nail to make many small holes in the end with the node. Wrap the wire or strong grass around the other end to stop it from splitting.



2. Wrap the strip of cloth around one end of the wooden rod until it is thick enough to be used as a valve; i.e.– it fits tightly inside the bamboo tube. Wrap and tie the material with string or wire to secure it. Make a handle and a stopper at the other end of the wooden rod. The stopper prevents you from pushing the rod through the node.



How to use the sprayer:

The sprayer is used like a simple pump or syringe:

1. Push the rod into the tube up to the stopper.
2. Dip the node end of the sprayer into the liquid, and pull the rod back to its full length. The tube fills with liquid as you pull back. Be careful not to pull the rod out of the tube.

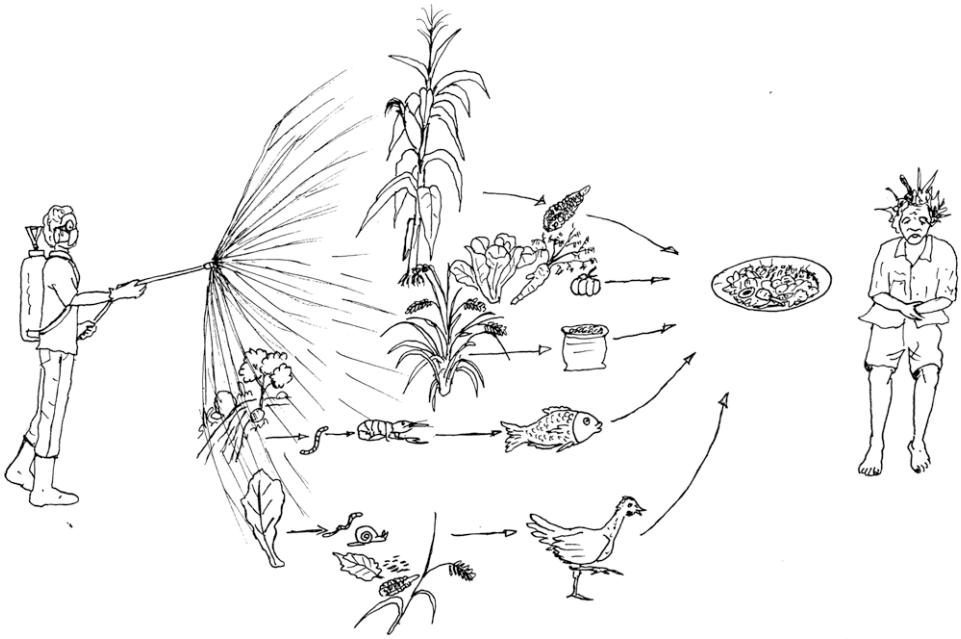
3. When you want to spray simply push the rod back in and the liquid comes out through the holes.

SMART IDEAS:

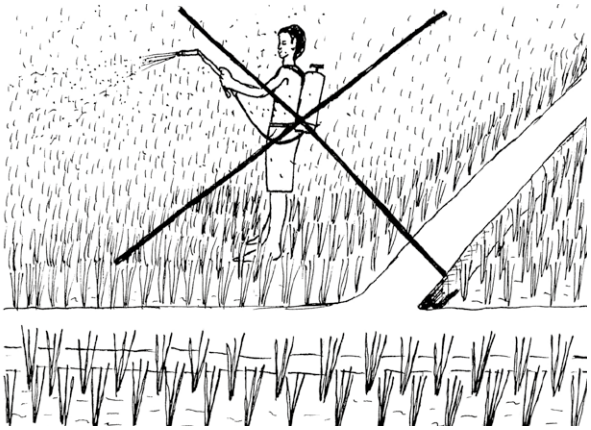
- Even with natural pesticides, always use protective clothing, gloves and a mask.
- Natural sprayers can also be made from metal or plastic pipes.

Danger: chemical pesticides, fungicides and herbicides!

- Chemical pesticides, fungicides and herbicides provide short-term solutions to pest problems but cause many long-term soil, environmental, health and financial problems.

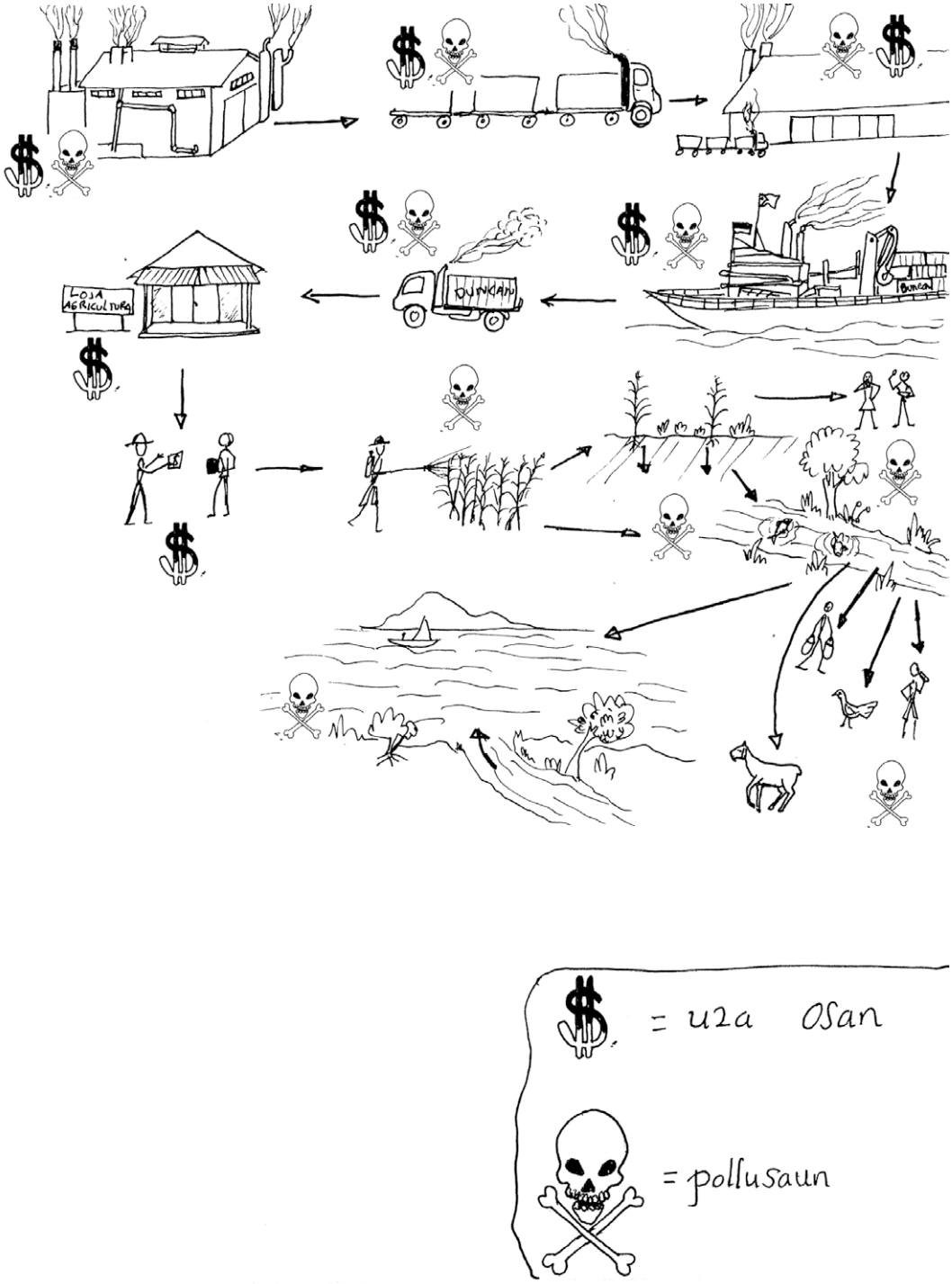


- Often farmers cannot read the instructions on how to use the chemicals so they misuse or overuse them, creating health and environmental problems.
- Pesticides kill not only the pests damaging your crops but many other good insects as well, such as those which improve your soil, pollinate your plants and eat the pests. The result is that your land is less productive and when more pests come there are no predators to eat them. Therefore, you will need to use the pesticides again and again and again and at higher concentrations. This creates dependence and ever increasing costs for farmers, the soil and the environment.
- Pesticides and herbicides are very expensive – too expensive for most farmers.
- Pesticides damage and kill a lot of soil biota (micro-organisms) which are essential for quality, productive soil.
- Chemicals are very dangerous to use without protective clothes, gloves and a mask and can make people sick, causing future health problems. Unfortunately, most people using chemical pesticides do not wear proper protection and have not been told about their dangers.



No protective clothing

- Making and transporting the pesticides also greatly damages the environment: Air, ground and water pollution are all created and cause long-term problems.
- The chemicals do not just disappear after the they are used. They can end up in the water – in rivers and the ocean – poisoning fish and water plants and causing health problems to people, animals and birds that drink the water and eat the plants and fish.



Chain of chemical pesticide production and use, showing how every step creates pollution and costs money

Other pests

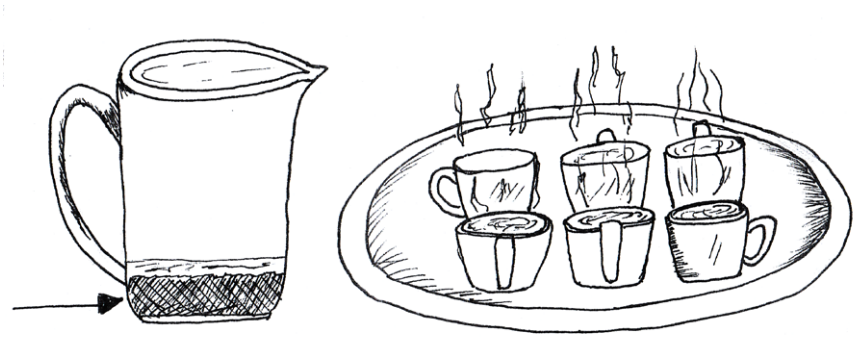
Ants

Ants cause problems through digging and removing seeds, damaging plant roots and by spreading other problems such as aphids, fungi and mildews. They can never be removed completely, but their effects can be lessened. And remember that ants also provide many important benefits for your garden: pest control, soil improvement, pollination and much more. So only control the ants that are doing specific damage to your plants. Preventative measures are best: read section 7. Preventative measures in this chapter for how to prevent ants damaging seeds, seedlings and trees.

For root damage try the following sprays: citrus skin, chilli/garlic/soap or tomato. See the natural pesticides section for recipes.

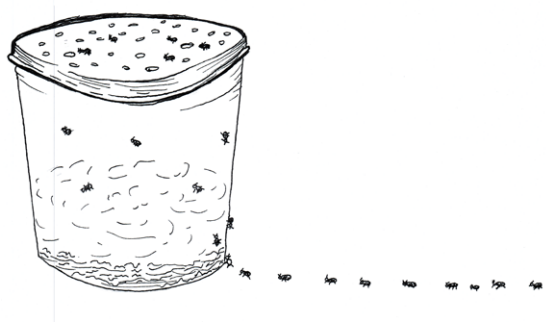
Other methods are:

- **Flooding with water** to remove ants from plant pots, nurseries and small garden beds.
- **Coffee (used grounds/powder)** and the acid in the grounds damage ants' skeletons. Place it around the plants that the ants are damaging, or mix used grounds with boiling water, and pour it over anthills.



- **Spraying treatment for nests:** Make up a spray containing 500 ml of water, 60 ml of kerosene, 60 ml of liquid detergent and 40 ml of vegetable oil, shaken together. Spray a circle of about half a metre's radius from the nest entrance. Pour a cup of water slowly into the nest entrance, wait a few minutes and spray all the ants on the surface with the homemade spray or a pyrethrum-based spray. Repeat this procedure every two to three days until the ant population declines. Additionally lay three to six baits as described below, around the nest.
- **Cornmeal controls ants.** Pour some cornmeal where ants are causing problems. They pick up the cornmeal, take it to the nest and feed on it. Because the ants cannot digest the cornmeal, they starve to death. It takes a week or so before you see results. Wheat flour and dried rice also work the same as corn meal.

- **Baits:** Use boric acid (borax) and sugar solution bait as a least toxic control. To make the bait mix three cups of water, a cup of sugar and four level teaspoons of borax powder. Half fill a small screw-topped jar with cotton wool, saturate it with the bait, screw the lid on tightly, and pierce several small holes in it to allow the ants access but prevent the removal of the cotton wool by larger animals. Keep the jar away from children and pets. It takes a few weeks to wipe out a colony but is more effective than using highly toxic pesticides that only kill the foraging ants, not the colony.

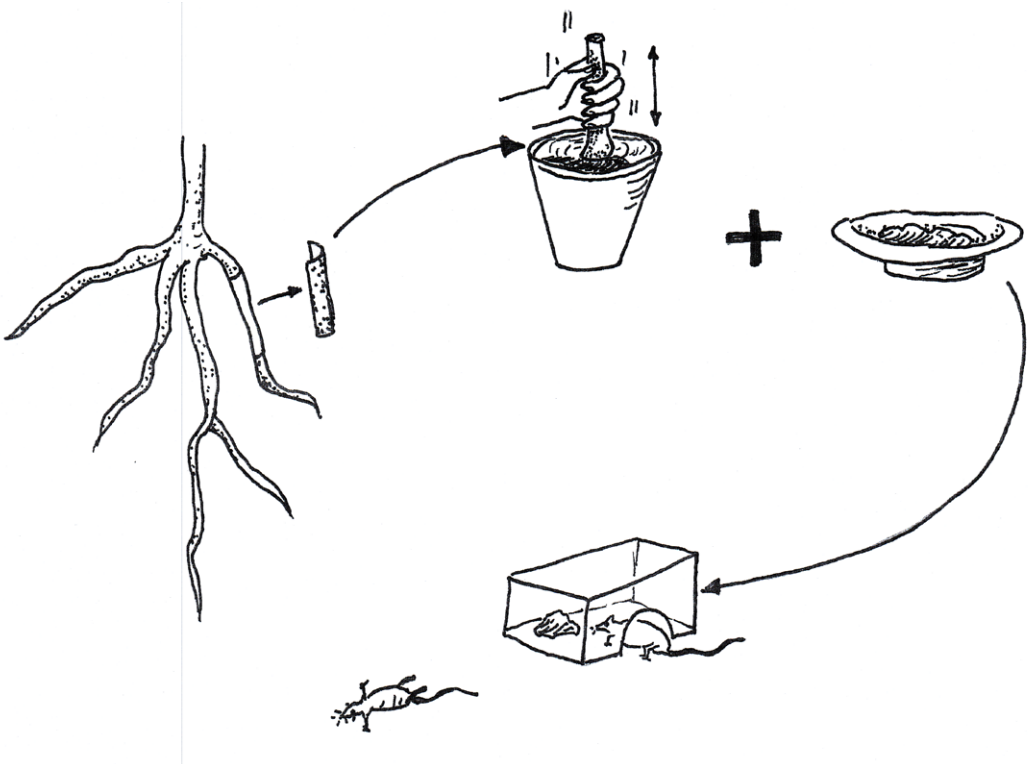


Rats and mice

Rats and mice are very destructive pests. Cats and dogs can help remove them from around the house and gardens close to the house. Dogs can be trained to hunt rats on your farm as well. Control methods are sometimes needed for larger crops. See Sustainable Agriculture (**Ch 13**) for good crop storage techniques.

A TRAP

Use the skin from 10cm long gliricidia root, crush, mix it with a little water to make a paste, and add a big handful of cooked rice with other tasty stuff. OR cook gliricidia leaves and bark together with some rice or grains to make the bait. Put it in a wooden box with a small hole to prevent dogs from eating it.



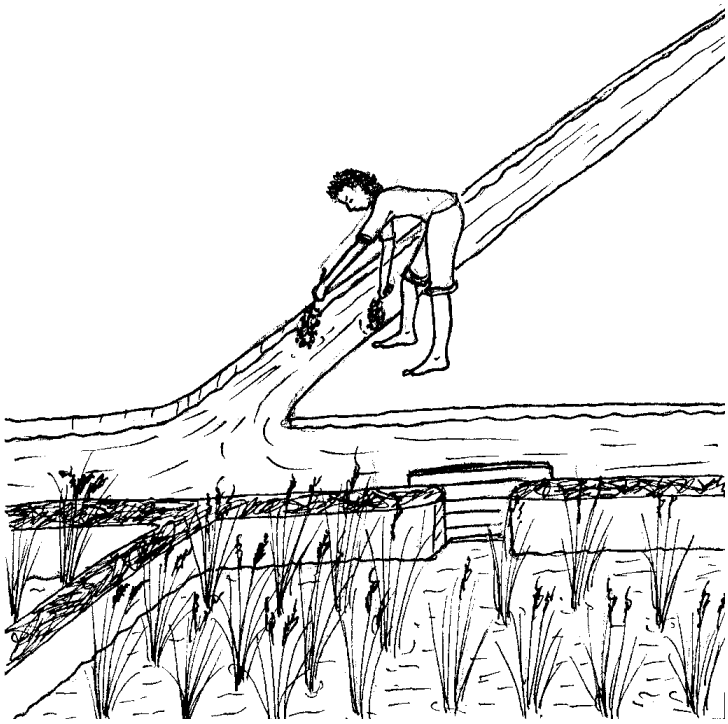
Black palm fruit in rice paddies makes rats itchy and deters them from coming back.

Method:

- Cut 20 to 30 black palm fruit in halves and put them in the irrigation channel where the water enters the rice paddies.
- When – Sunset
- How often – three times a week when the rice grain is ripening.

Be careful:

- People who wash downstream may be affected.
- Too much fruit is poisonous and could affect the health of people harvesting and eating the rice.



Chickens, ducks, pigs, goats, cows and buffalo

Either fence in or fence out animals that may destroy your plants. This means building a permanent home for your animals, or building a high fence around your vegetable gardens. If it is common in your community for animals to roam free, a fence for your vegetable garden is essential. Protection for trees, especially young ones is also important. See the chapters on Animals (**Ch 17**), Trees (**Ch 15**) and Family Gardens (**Ch 10**) for more ideas.

Monkeys and other native animals

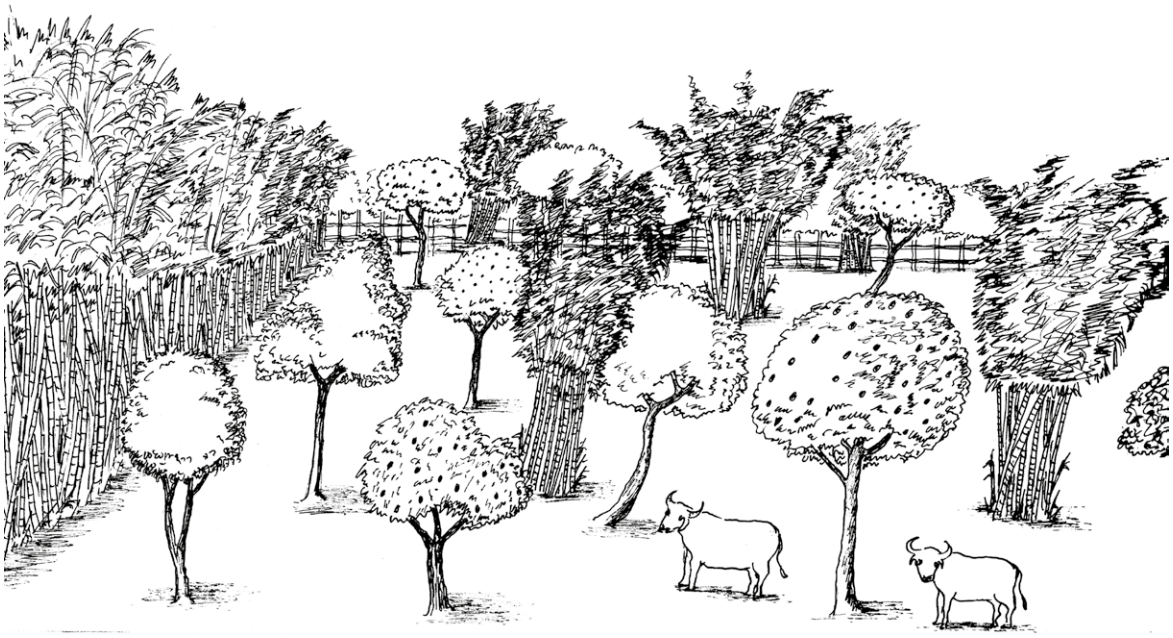
It is a balance that humans must find – growing food for ourselves and having a healthy environment with many native animals. These animals can cause huge damage to crops but if we remove them and their habitats, the earth will quickly become impossible to live on for humans as well.

This is an issue which needs many solutions. On a national and an international level forests, ecosystems and the animals, birds and insects in them must be protected. National parks are an important part of creating a sustainable balance. Even in and around farming areas, providing native animals with diverse healthy habitats is essential, but must be combined with control methods for protecting crops and livestock. Preventative control measures are by far the best. Farmers and communities must be included in designing and implementing solutions.

Some preventative measures:

- Guard animals – a few dogs can be very useful to protect your crops from monkeys, deer and other small native animals.
- Fences and living fences.
- Protection crops such as cactus or bamboo with large thorns.
- Traditional traps.
- Strong chilli and very bitter plants can be used to make sprays to act as deterrents in the dry season.
- Plant food trees for native animals but far away from your gardens and productive trees.

Guard animals

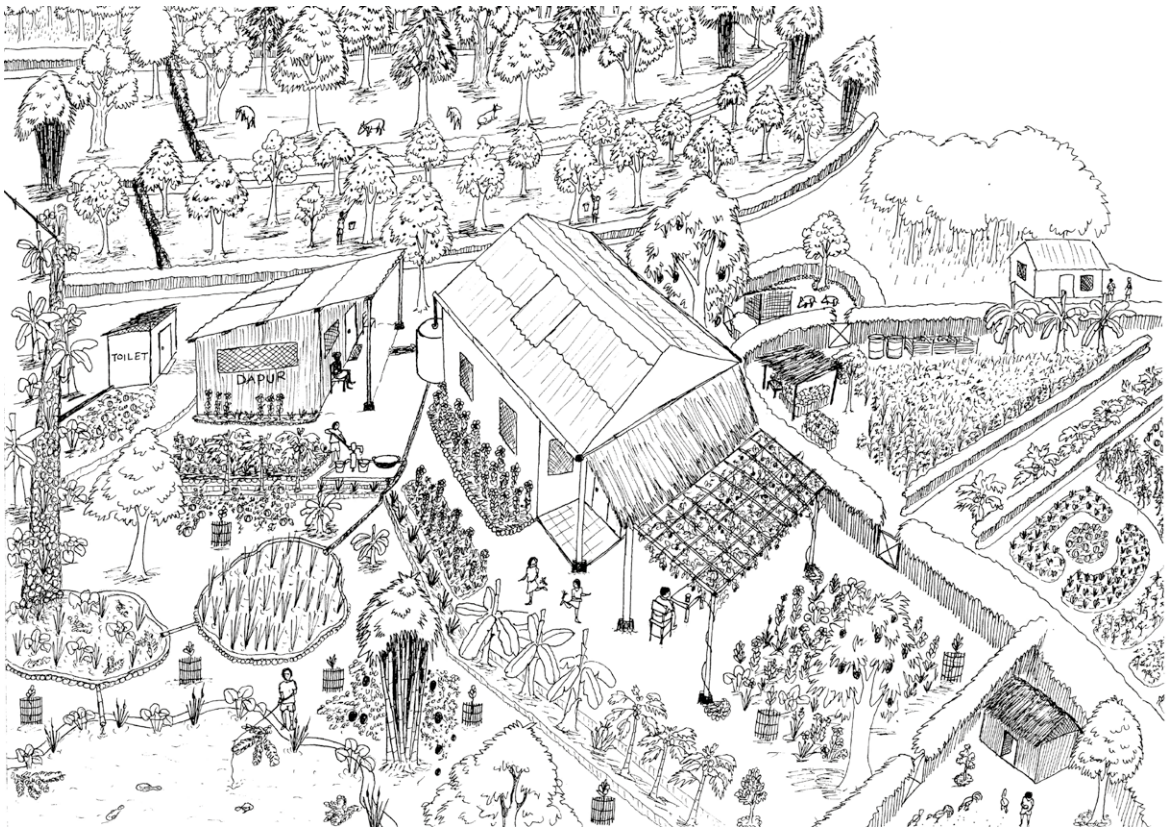


Thick bamboo living fence to protect trees and crops

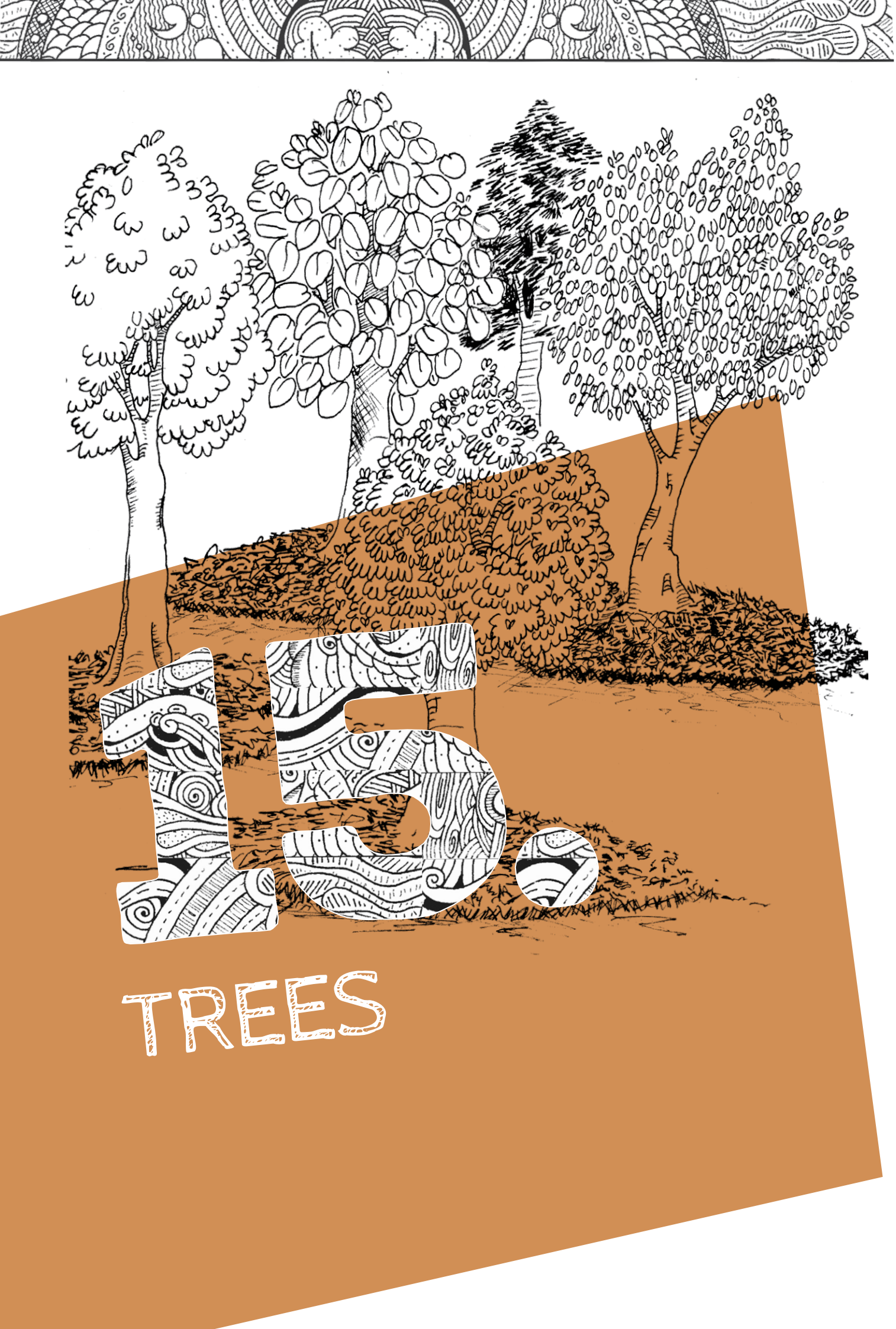
Remember: MOST INSECTS ARE NOT HARMFUL TO YOUR CROPS!!!

All insects have a role in the natural environment and are needed for a balanced ecosystem.

Even pests should exist in small numbers to provide food for the pest predators. To remove all the pests creates further imbalance and dependence on pesticides. IPM is a strategy that improves your land and crops, especially for the future. The techniques naturally combine with other permaculture techniques to create a strong and resilient farming system.



How many IPM strategies can you find in this picture?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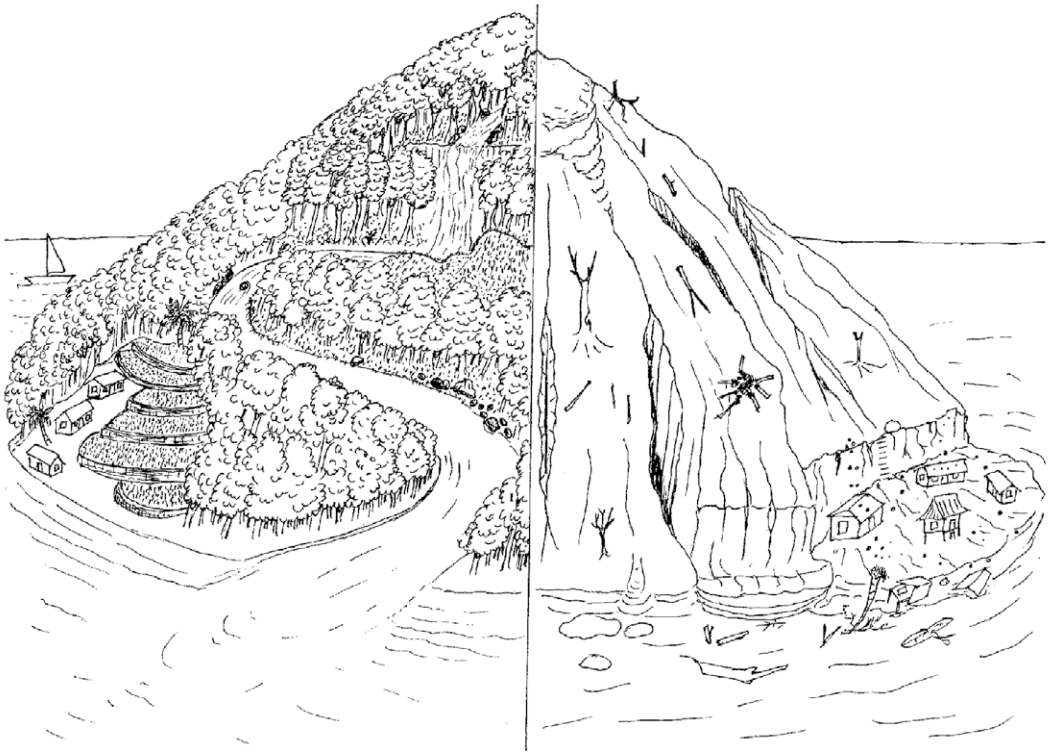
Trees are life

Forests are formed from individual trees and they are the earth's lungs, giving life to every living thing. Forests provide us with clean air and oxygen as well as food, timber, fibre, oil, clothing, fuel wood and medicine. They provide homes and food for animals, birds, insects and countless other creatures, many of which are too small for us to see! Forests also preserve ground water, protect land from erosion, attract and improve rainfall, and are seed banks for the future.

Forests create and preserve healthy and diverse environments as well as cultural identity and heritage for local communities. They are places of inspiration and beauty. The people of tropical cultures believe that forests hold spiritual connections between humans, their ancestors and nature.

Forests have complex ecosystems in which every plant, animal, insect, fungus and bacterium is a vital part of the forest. Many of these are unique to each country or region owing to the different climates, soil and the natural landscapes – the way the land was formed long ago. Preservation of these species is essential to maintaining the health and balance of forest ecosystems and helps to retain the different people's cultures and their heritage.



Areas that have forests need to be protected and carefully managed. Forest logging, burning and land clearing practices are destroying forests, damaging cultures and contributing to climate change. We must replant, protect and sustainably manage the forests, especially along rivers and water catchment areas. Burning and land clearing must be stopped and reversed; they are short-term gains that create long-term disaster. Animal grazing must be well controlled. The next steps are to reforest areas and restore the environmental balance. We must maintain strong connections to the land. Tropical countries need long-term solutions to provide for the future and for the environment to be healthy and strong.

Where the land is mountainous with steep slopes forest removal is causing massive erosion and loss of soil. Good productivity is impossible on land where soil is depleted and erosion is bad. Often growing crops in such areas can lead to more erosion and other problems.

Reforestation and growing tree crops are great solutions because:

- Tree crops are much more stable and reliable for a changing unpredictable climate. Products and income from trees and forests are more secure because tree crops are less affected by bad weather conditions.
- Large tree crops and reforestation areas actually attract rainfall, increasing rain in dry areas, especially in mountainous regions.
- Ground water is preserved and, when reforestation occurs on bare land, it replenishes the ground water supply and dry springs start running again.
- They help to stop erosion and repair damaged land AND provide food, timber, firewood, oils, medicine, fibre, income and more. These aspects are security for the people and for the future while providing sustainable incomes.
- Tree crops can also be integrated with animal systems and annual crops.
- They add to food diversity for people, animals and birds, and produce can be used, sold or traded. A well-designed forest system requires little maintenance once it is established. Forests and tree crops improve environmental health, not just on the land where they grow, but for the surrounding land as well. The improvement occurs all the way to the sea, and even improves the marine environment. This is important for everyone!
- Air quality improves with reduced burning and erosion and more trees producing oxygen.
- People's spiritual connections to the land remain strong when the forests and environment are healthy.
- Ecotourism opportunities develop because people want to visit beautiful places, learn about different cultures and even to help with reforestation projects.

Changing habits and practices can take many years. The process, however, starts with just a single step.

Healthy and sustainable forest systems

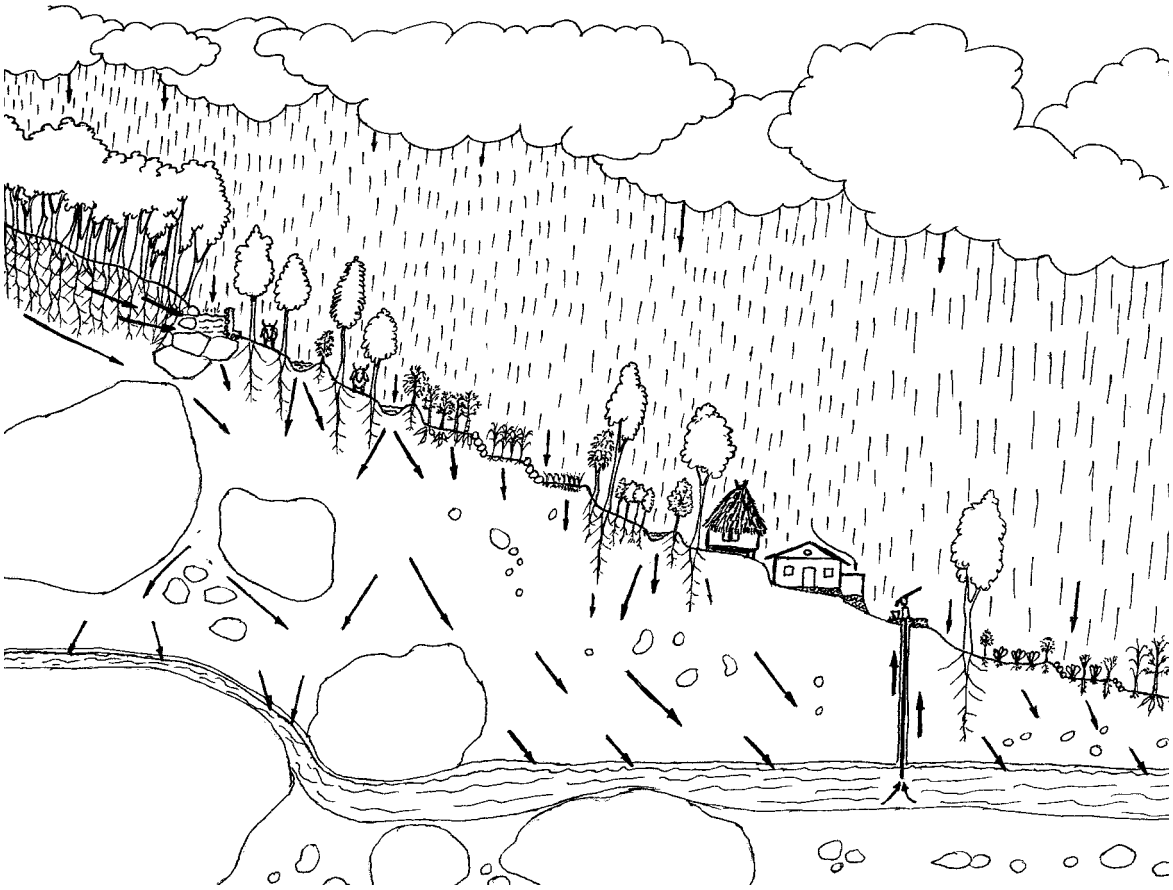
Productive trees and tree systems including flood prevention and windbreaks are part of the village design

To create healthy, sustainable forest systems people need to:

1. Store water in the ground.
2. Protect the soil and stop erosion.
3. Control domestic animals.
4. Stop burning!
5. Develop a community management plan.

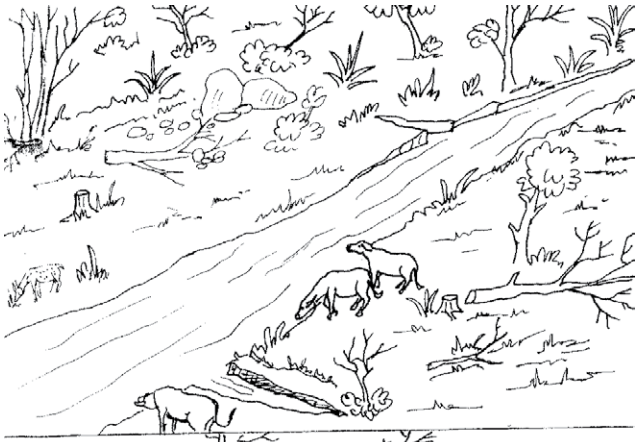
1. Store water in the ground

- Water is precious!! Any water that is stored in the ground benefits the land, the plants and the people.
- When water is collected and stored in the ground it protects the soil and greatly reduces erosion.
- When water is stored it extends the annual crop seasons.
- Trees grow better in the dry season and produce better crops with access to stored water.
- Ground water levels increase when water is collected. Storing water means springs are more constant and less likely to dry up.
- Trees also store a lot of water.



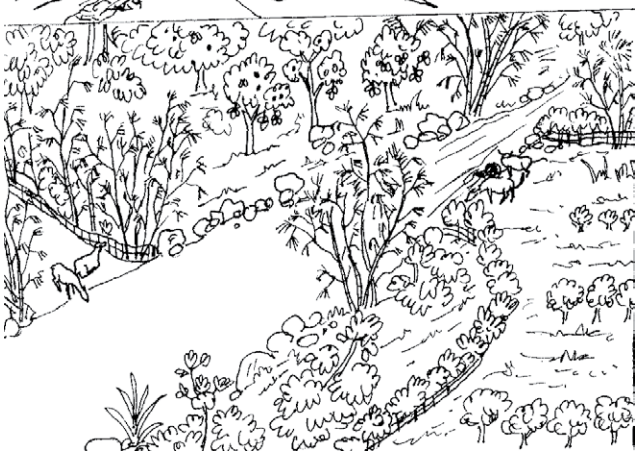
2. Protect the soil and stop erosion

- Erosion reduces productivity by removing valuable soil.
- Soil, especially good soil for agriculture, takes time to create but disappears very quickly due to erosion.
- If it is uncontrolled, erosion quickly gets worse and makes bigger problems for the future.
- Erosion results in the loss of small plants, seeds and organic matter.
- Land clearance and erosion can lead to landslides that not only destroy land but endanger homes and people.
- Reforestation and tree crops are the best long-term solutions to protect soil and stop erosion.
- Erosion slows the flow of creeks and rivers with soil build up. This reduces fish, other aquatic animals and plants and stagnant (slow-moving) water creates disease. Rivers and creeks are also important breeding grounds for prawns and some marine fish so damage to rivers also impacts these breeding areas.



River - Present day

River - Future if no reforestation and no management



River - Future if reforestation and good management

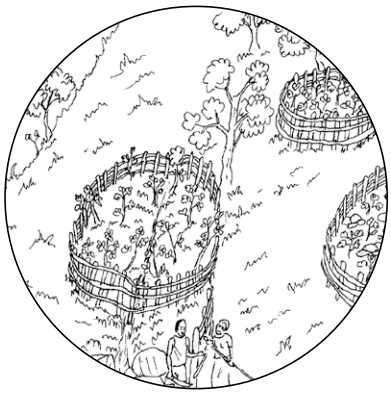
Swales, terraces and other water catchment techniques which hold water and provide an important base for reforestation, tree crops and agriculture on sloping land, are explained in detail in Permaculture design strategies and techniques (**Ch 3**). There are specific tree-crop techniques given later in this chapter as well.

3. Control animals

Animals, especially goats, destroy reforestation and tree crops very quickly. This wastes a lot of hard work and valuable resources.

There are many solutions that suit different situations:

1. A traditional land-protection ceremony, such as Tara Bandu in Timor-Leste, can be performed to protect an area. Read 'Traditional law for natural forest management' later in this chapter.
2. The tree crop/reforestation area can be fenced to keep animals out.



3. Each tree may be protected by a tree guard.

4. When the trees are well established animals can be **carefully** managed to graze the land.

The best solution is a combination of techniques, and **community cooperation is essential for success.**

4. Stop burning!

- Burning increases erosion problems.
- Burning reduces the diversity of plants and animals.
- Burning encourages plants that like fire, which are usually plants that are not very good for people, crop production or the environment.
- Burning destroys mulch and organic matter that are very important for good soil.
- Burning increases water loss.
- Burning damages healthy soil because soil biota is destroyed.
- Burning creates pollution harmful to humans and the environment.
- Burning destroys reforestation and tree crops.
- Burning creates CO_2 – carbon dioxide – which contributes to climate change. If farmers across the world stop burning, they not only improve their soil and their production but also reduce the impact of climate change. If we change practices now, we can still prevent some of the worst effects of global warming.

Burning every year produces systems with low productivity. Highly productivity systems and integrated systems are damaged or destroyed when the land is burnt.

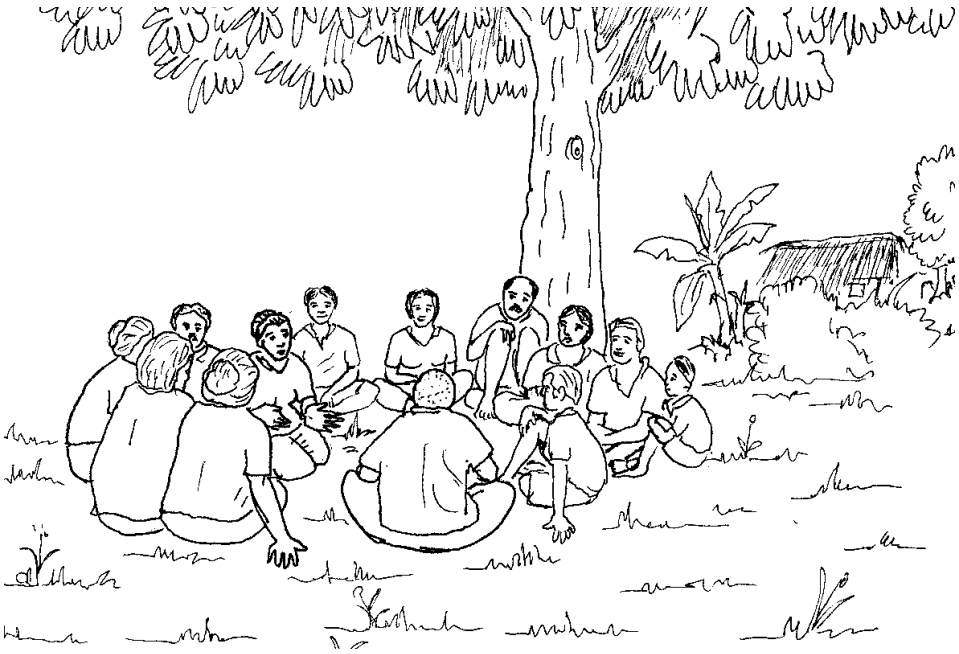
Many areas are burnt to encourage the growth of new grass for animals. This encourages low quality grasses to grow and removes other vital animal food, such as legumes, which also provide nitrogen for the soil.

Burning can be reduced and eventually stopped as better techniques are introduced. This guidebook provides solutions and productive methods that stop the need to burn by providing better alternatives, such as using ash from kitchen fires and burning bamboo poles specifically for ash and charcoal. Read more in **Ch 9** Soils.

5. Community management plan

A community management plan is essential for sustainable forest management to work. All community members should understand why it is needed and contribute to the solutions.

Traditional land-protection law and ceremonies, such as Tara Bandu in Timor-Leste, preserve sacred land, community forests and reforestation, especially on fragile land and next to rivers. This has been very successful in Timor-Leste and is highly recommended as part of any forest management system. Read more at the end of this chapter.



Community meeting

The community management plan must:

- Plan for the future.
- Plan for what can be harvested, from where and when, and who can harvest it.
- Plan for who receives income and how much goes back into community forest management.
- Work with the government.
- Not allow any major land clearance and do not give land ownership or rights to companies, especially foreign companies.
- Look at creating sustainable local businesses that use forest resources wisely: e.g. seeds, medicines, quality furniture, oils, bamboo products, nuts, honey and many more.

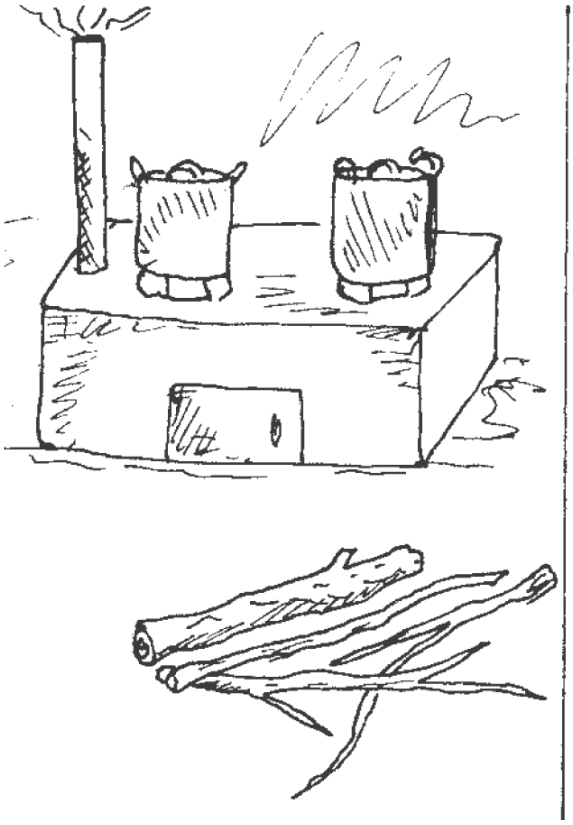
An important example:

Collecting firewood has caused a huge reduction in trees and changes are needed so that the problem does not become worse. Collecting firewood is also very hard, time-consuming work which is mostly done by women and children. Reducing this work improves life a lot for women and the whole family, as well as protecting vital forests.

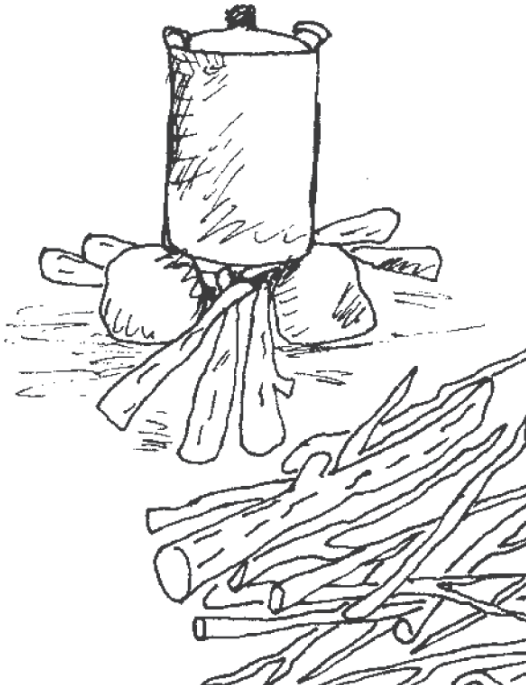
Solutions are:

- Use stoves and ovens that use less wood or do not use wood al all, including biogas.
- Replant more firewood trees than what are being used or sold.
- Plant firewood trees closer to the house, including growing living fences.

See Food, Health and Nutrition (**Ch 8**) for many different stoves and ovens.



Use a small amount of wood with a stove or oven



Use a lot of wood with an open fire

The solutions and techniques in this chapter will improve and strengthen your community's future. Part of this must be teaching children to care for the land, reforestation, and to stop erosion and burning.

Productive trees and permaculture tree systems

Productive trees are essential for our food, medicine, shelter and income.

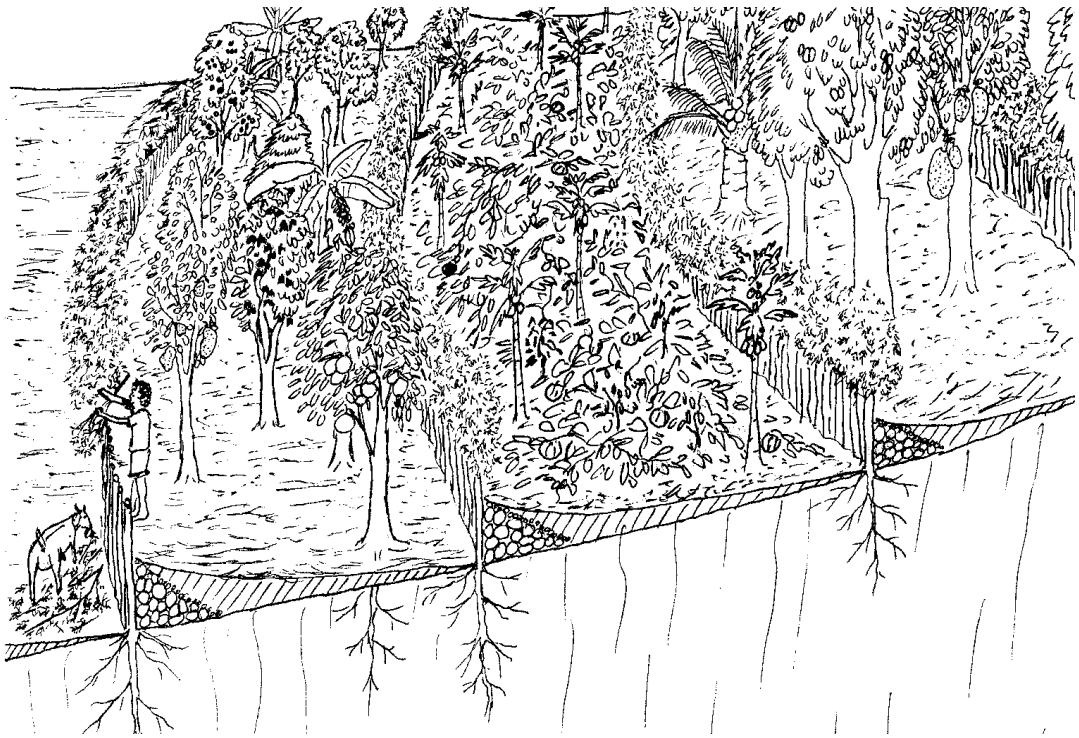
As climate change becomes a bigger problem, crops from a range of trees become more and more important because trees are more resilient than grains, vegetables or annual plants.

Often trees are just grown individually with no fertiliser, pruning or maintenance. This achieves low production with no work.

If the trees are maintained well using organic techniques, production increases a lot with some work involved.

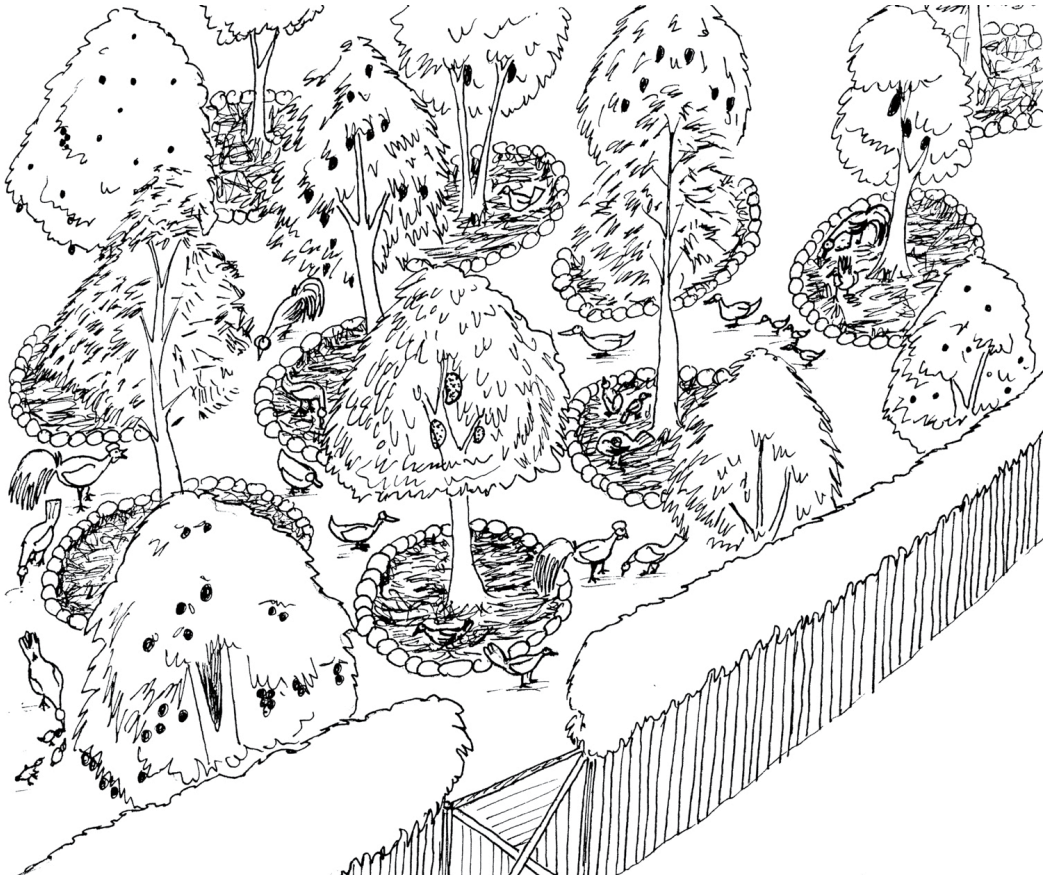
If the trees are part of a permaculture system, production stays high, and a lot of the maintenance is done by other parts of the system, but not by you!

Using organic techniques in a permaculture system maximises tree health and production, and is mostly self-maintaining.



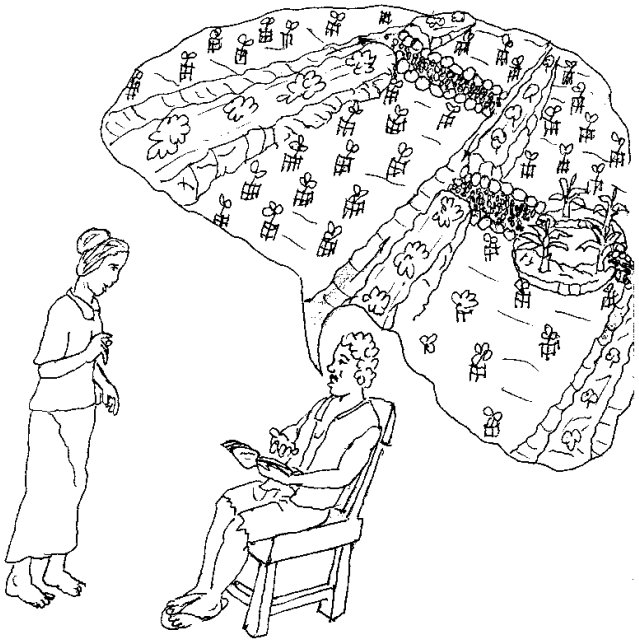
There are many different systems for growing highly productive trees using permaculture and organic methods. What you decide to use is up to you. It depends on:

- What types of trees you use
- The resources available
- What other types of production you integrate
- Land, soil, water, rainfall, wind, altitude, climate and degree of land sloping



It is very important to choose a range of trees and the right trees for the growing conditions. With permaculture tree systems you can create new microclimates to allow a wider range of trees to grow well in the conditions you have. Read about microclimates in Permaculture design strategies and techniques (**Ch 3**).

These techniques are for new projects as well as to improve productivity for existing trees. They can be used by families, groups of families or by communities.



Preparing the land

Make a detailed design for the land before you do any work. Read Permaculture design strategies and techniques (**Ch 3**) to help the process. By first doing a site analysis and making a design you can make the most use of the land, the best use of your time and minimise mistakes.

This is the same for establishing a new system or redesigning an existing system.

For sloping land: swale and tree terrace systems

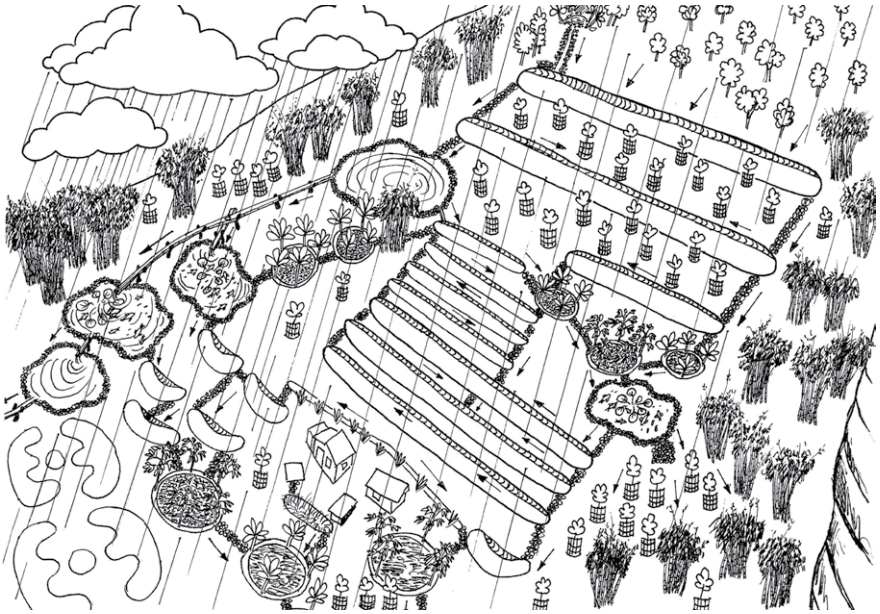
Swales, terraces and other good water management techniques are used for many different systems and are very important for large areas of land. The information on how to design and construct them, including secure overflow points, is clearly explained in Permaculture design strategies and techniques (**Ch 3**).

This section builds on Chapter 3 to explain water catchments, including swale and tree terrace systems, for tree crops, food forests and reforestation areas.

A swale is a trench dug in a line along the contour of a piece of land with a mound of soil, rocks or other materials made in a line directly below it. It is built to collect, spread and store water in the ground, and also to catch soil and organic matter. Often on land that is large, too hard to dig, has too many rocks or too much slope only the mound is made, from rocks and other materials.

Swales provide many important benefits for agriculture and tree crops. They:

- Stop erosion
- Improve the soil by holding compost, manure and mulch
- Catch and spread rain and irrigation water
- Extend the wet season by weeks and reduce problems from dry spells during the wet season because they hold extra water in the ground
- Create new microclimates on the land
- Water that leaves the swale system via overflow points can then be directed for further use – dams and check dams for irrigation, aquaculture ponds, banana pits, rice paddies or soaked up by tree crops.



Swales, terraces, dams and other water catchments improve the land and production. Importantly, they also move water back into the ground which refills underground water supplies and provides permanent and secure water for irrigation and communities.

IMPORTANT: For all water catchment systems, especially in regions with steep slopes and/or limestone, plant fast-growing legumes straight away to secure the soil and minimise the potential for landslides. Trees that grow from seeds planted straight into the ground grow roots much faster than planting seedlings and are better for securing the soil. Over time, the fruit and production trees grow up and replace most of the legumes.

Types of water catchments

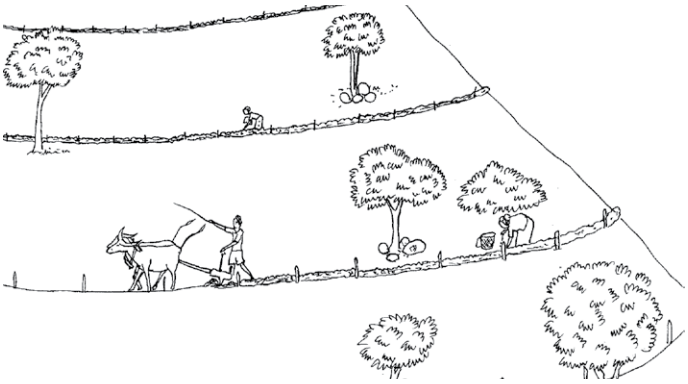
There are three main types of water catchments.

TRENCH SWALES

Dig a trench, and put the soil and rocks that are dug up below the trench to form a mound.

PLOUGHED CONTOUR LINES

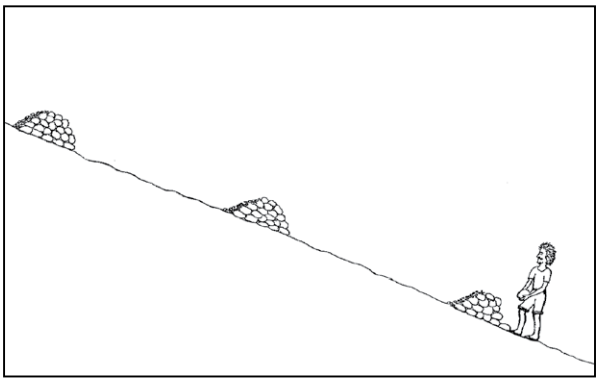
Use a buffalo to plough a line along the marked contour.



ROCK SWALES

Make a mound or small wall from rocks instead of digging. Usually rock swales are made where:

- The land is too hard to dig because it is too dry.
- There are too many rocks.
- There is a steep slope.



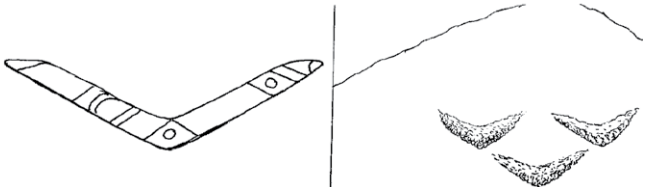
Which type you use is up to you: You can use both types on the same land if you choose.

All three types should be planted immediately to:

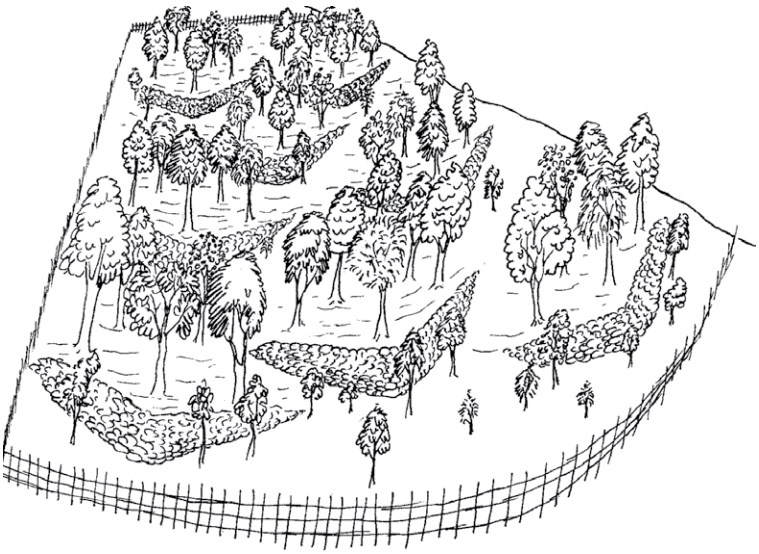
- Hold the soil.
- Provide future tree terraces or "living" terraces.
- Provide mulch and nitrogen.

Boomerang water catchments

Boomerang water catchments are named because they look like boomerangs, which are a traditional hunting weapon of the Australian Aboriginal people. They are explained in detail in Permaculture design strategies and techniques (**Ch 3**).



They are small catchments dug out or built with rocks or both. They can be great for single trees or small groups of trees. If you make many boomerang water catchments together in an area, they can feed any excess water from one to another. This improves the results and productivity of all the boomerang water catchments.



Net and pan water catchments

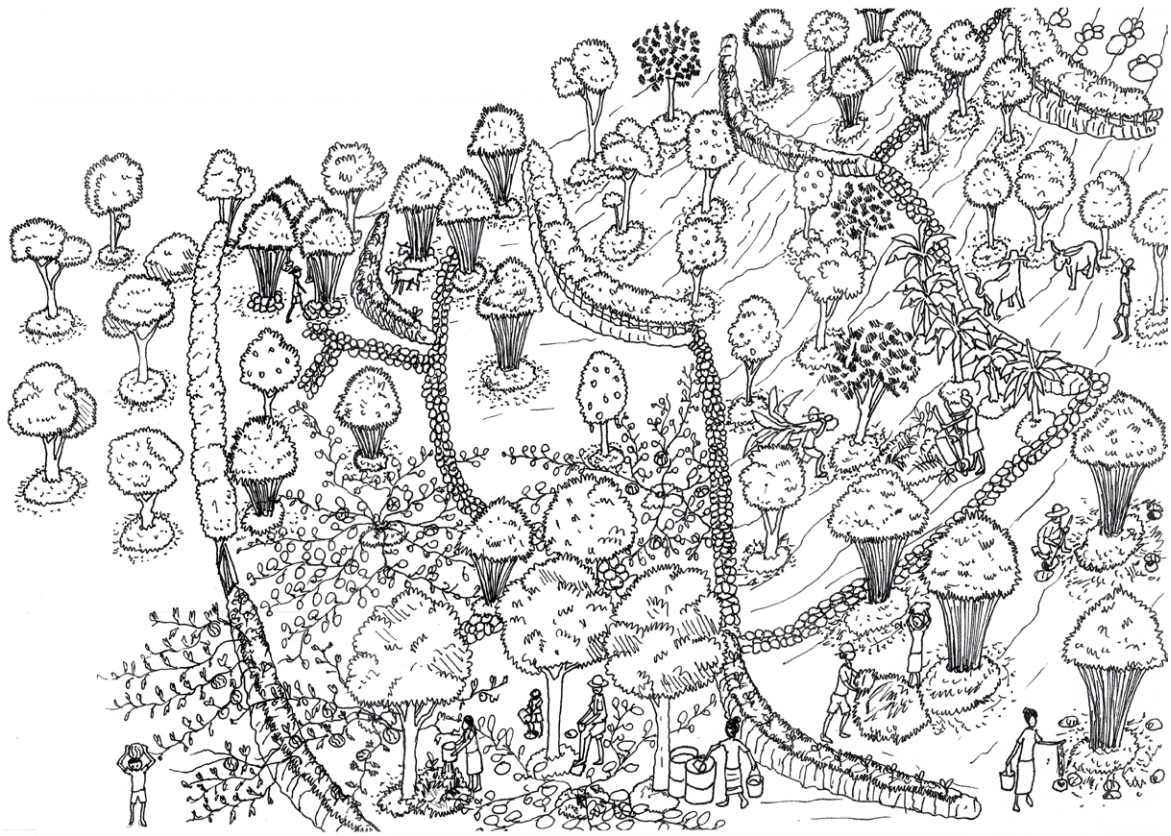
This system is best for gently sloping land. It is called "Net and Pan" because a "Net" is made to catch water and a "Pan" holds the water. The technique is similar to the boomerang water catchment but it has a V shape.

Each side of the "V" is about three metres long and about knee high. They are made from stone or dug out. A combination of both is good.

If many "Net and Pans" are made together they make a system where the overflow from one pan runs via the net into the next pan and so on. Use small trenches or rock lines as nets to connect the V shapes and direct the water.

WHAT ARE THE BENEFITS?

- Every tree planted is healthier and more productive because there is more water and the soil builds up and improves.
- There is a lot less erosion.
- Each "Net and Pan" can be planted with short-term and long-term crops.



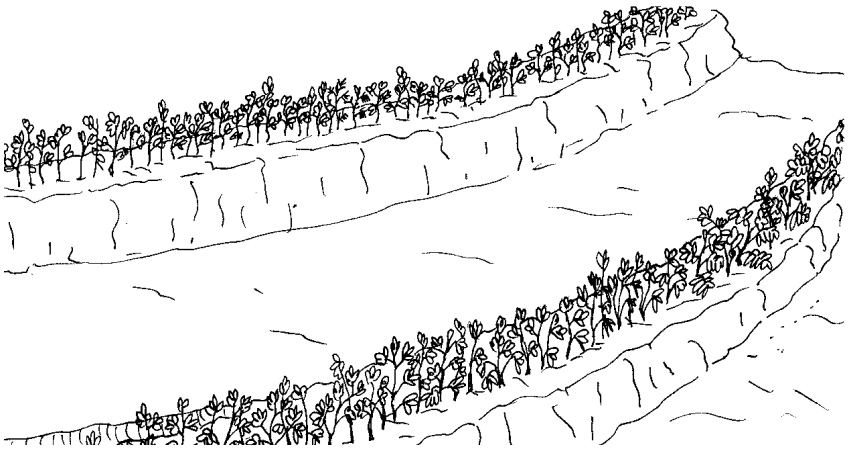
SMART IDEA:

Use whatever technique suits your needs, and try your own ideas for slowing, storing and spreading water.

Tree terrace systems

PLANTING ON SWALES OR PLOUGHED CONTOUR LINES

Plant fast-growing legume tree seeds along the top of the swale mounds or along the ploughed contour lines at the start of the wet season. Plant them very close together – 10cm apart.



Tree terraces just planted

These legumes have many uses:

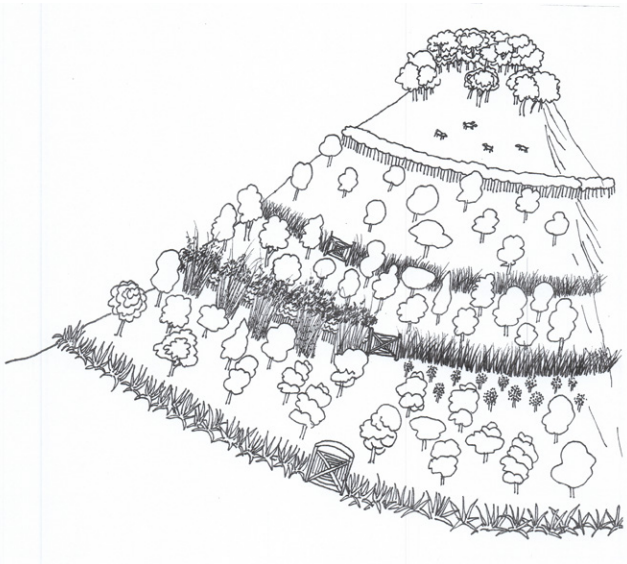
- They hold the soil together and eventually form a hedge that can be continuously pruned for many years. The material pruned is valuable mulch and fertiliser and, as you prune the legumes, their roots release nitrogen into the soil.
- The legumes also act as a windbreak and help to protect young trees and annual crops.
- After two to three years the legume hedge turns into a living fence.
- Natural terraces are eventually created.

Gliricidia, sesbania, pigeon pea (*Cajanus cajun*), crotalaria (or rattle pods) – be careful because it is poisonous to animals – and leucaena, albizia and calliandra are the best legumes to use. For the first season, grow a crop of beans and pumpkins as well.

Other plants that are very useful along the tree terraces and next to the overflow points are:

- Vetiver grass, lemon grass and other perennial clumping grasses. Be careful not to use grasses that might spread and become weeds. Vetiver grass is good for all situations, especially steep slopes, as its very deep roots secure the soil.
- Small clumping bamboos are very useful and can be part of a living fence.
- Pineapples can be planted next to legumes and are very tough.

The ploughed contour lines or swales planted with legume trees, grasses and other plants create living fences along the contour lines. The land is naturally divided into sections. These sections are where you can plant tree orchards, food forests and agroforestry systems as well as integrating animals once the trees are well established.

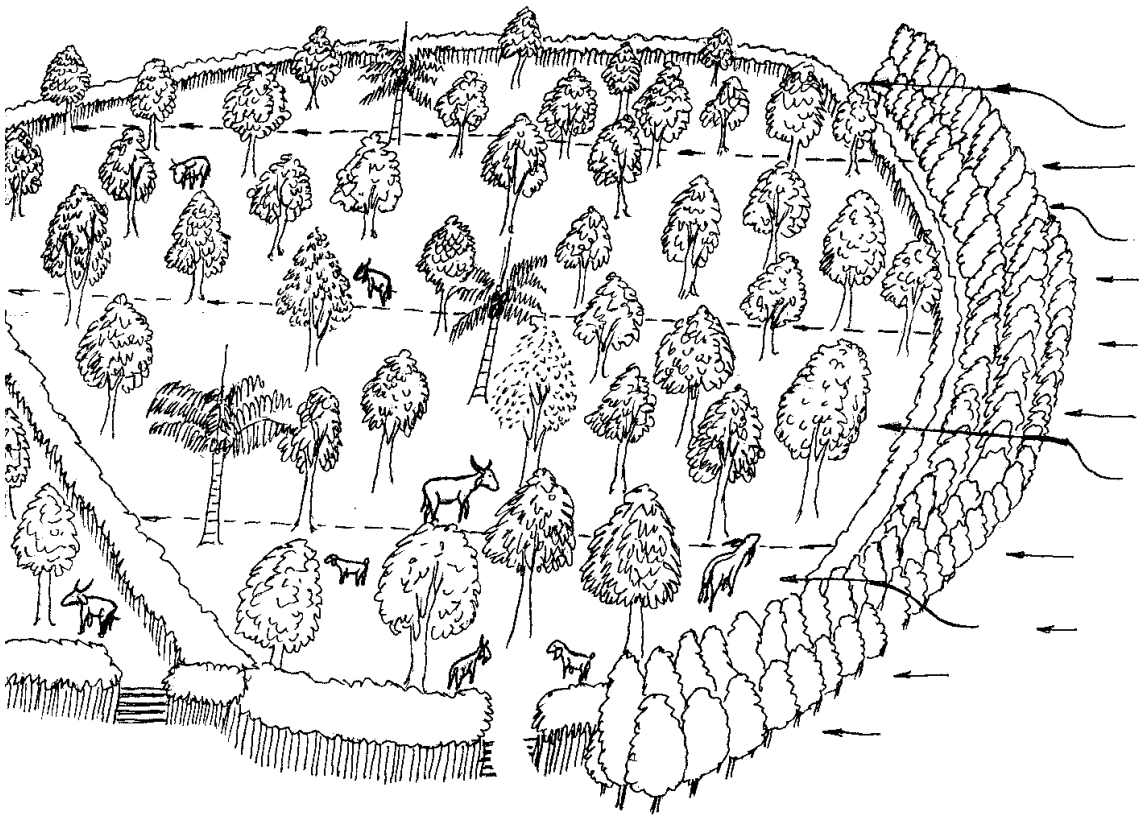


For flat land

Flat land is often used for vegetable and grain crops. However, tree crops can be integrated with grain and vegetable crops in many ways. The tree crops increase the number of different crops, and can also be used to improve the production of grains and vegetables. Tree crops are especially good in dry areas and provide more stability in an uncertain climate.

Dividing the land into sections – such as swales do for sloping land – can be a good technique for flat land too. The benefits are:

- Living fences provide the opportunity to include animals in the system.
- Nitrogen, mulch, compost materials, animal fodder and food are produced.
- Water movement and storage are easier to control.
- Pest problems can be controlled more easily because it is harder for the insects to go from row to row. The trees provide a break and a barrier.

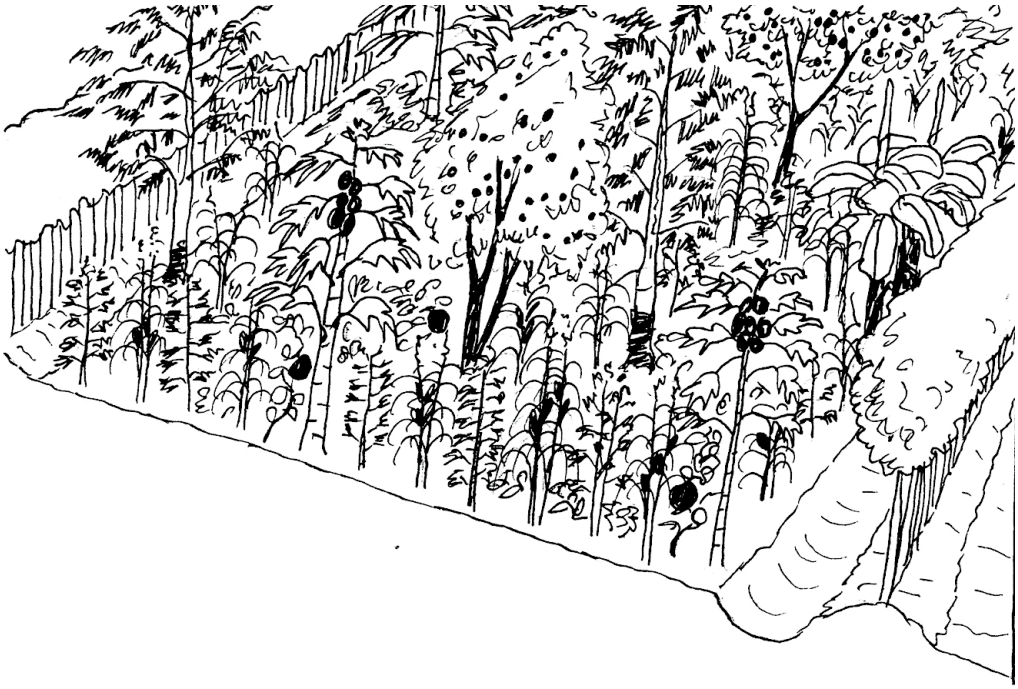


A flat land orchard with living fences and windbreak

Water management for flat land

On flat land each tree should be planted with a catchment circle that is slightly raised above ground level. This holds water in the dry season but helps water to run away and not flood the trees in the wet season. Even on flat land, water moves when there is a lot of rain. Create fish ponds, rice paddies and banana pits to store water and move it away from trees to other areas, especially in wetter tropical regions.

Design your system to reduce and prevent flooding. This includes identifying and managing water coming onto flat land from hills and mountains nearby. Swales, trenches, ponds, small dams and banana pits can slow, store and spread the water. This water can then be used to irrigate the trees. If the land is mostly flat, try to follow contour lines with your trees and use the swale designing techniques for good results. The lines of legume trees and other plants help to slow the water and spread it to where you want it to go.



Flat land tree crops improve if trees have good drainage - allowing water from heavy rains to flow away - and most rain is collected and stored in the ground.

For dry land

In the drier tropical regions water storage is especially important.

In dry areas often the ground has many rocks. In these areas rock swales and rock terraces work very well. Use different techniques and patterns to protect soil and water and improve results.

Living fences and techniques for sloping and flat land are still important, but choose tree and plant species that can survive much drier conditions, including no rain for long periods.

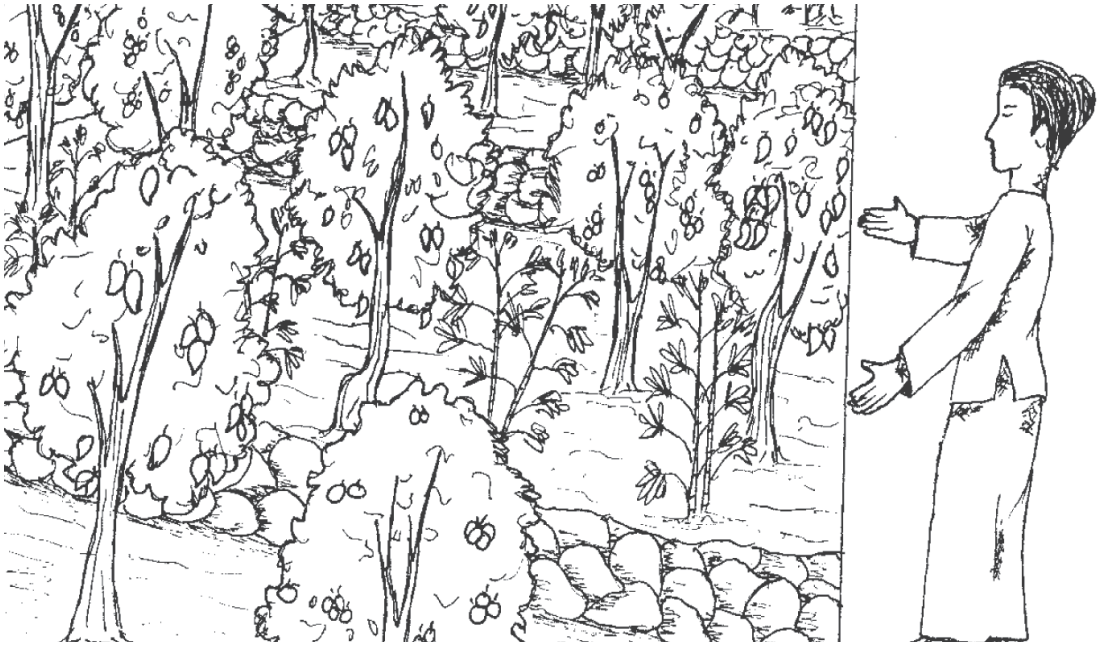
Strong fences and tree guards are high priorities because goats are common in drier tropical regions and can destroy trees very quickly!

Mulch and rock mulch are vital in dry lands. (See **Ch 9** Soils - Mulch section) Do not just use them: an important part of your design is also to grow plants that can provide the mulch.

The following techniques can be used anywhere, and can also be used for sustainable agriculture.

Look at my rocks!

The rocks are a solution!



The rock swales hold the water, soil and mulch to create a productive system, even in dry lands

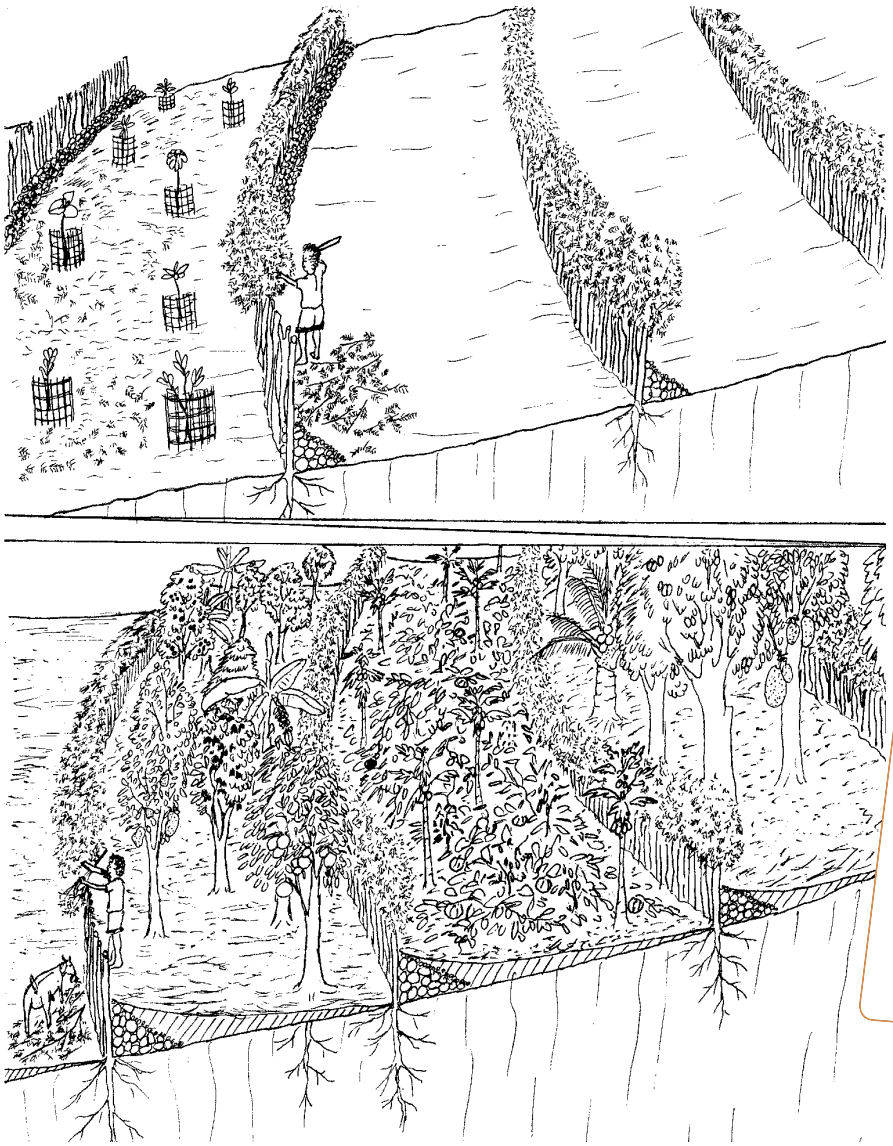
Planting plans

You can plant many different crops: fruit trees, nut trees, productive trees, perennial shrubs and small plants, and annual vegetables. Animals can also be integrated. The more diverse your crops and animals are the better. Do not rely on one type of tree for income. Always obtain a yield, even in the short term: fast-producing fruit trees and root or vegetable crops are very important for food and income while the long-term trees develop.

The types of tree crops you choose depend on:

- Which tree crops grow best in your area?
- Can you create good microclimates to improve conditions and increase the variety of trees that grow well?
- Which tree crops provide different harvest times and income during the year?
- Which tree crops provide food, timber, firewood, mulch and other resources?
- Do the trees you want have good disease and pest resistance in your area?
- Can you grow crops under them or will the leaves block out too much light?
- Are the trees easy to harvest?

The choices should be made together with all the members of the family and community who are involved and who will use the crops. Remember always to choose the right species for the right climate and the right location – too often people choose the wrong trees and wonder why they do not grow well!!



Established rock swale system with legume tree rows and a diverse range of tree crops

SMART IDEA: Choose different trees to suit different conditions:

- Drought-tolerant trees for dry conditions
- Water-loving trees for wet areas
- Tough trees for poor soil
- Other conditions to consider include high altitude, steep sloping land, or flat flood-prone land.

Introducing new tree species

BE CAREFUL: If you want to introduce new types of trees or plants, especially from overseas, do some research to find out if the tree could become a problem in the future.

- Will it become a weed problem and take over local trees and plants?
- Will it introduce new pests or diseases?
- Has it caused problems in other countries or regions?

For example, eucalyptus trees from Australia are now a big weed problem in South America, Southern Africa and Southern Europe, outcompeting local trees, increasing fire risk, reducing animal and bird food and damaging the environment. Preventing this type of problem is very important for protecting the environment and resources for the future. Prevention is MUCH easier than trying to fix it later!

The following examples can all be used for sloping land, flat land, dry land and high altitude land. They are based on creating sustainable, productive and resilient systems, and can be integrated, mixed or changed as needed. The types of trees and plants are different from place to place, depending on which grow best and what you want to grow. Every situation is different!

We give as many different ideas as possible but be willing to experiment, and use your own ideas and knowledge to change and improve the techniques.

Food forests

The "food forest" is a strategy of creating a productive ecosystem that imitates a natural forest. Natural forests do not have grass around the trees; they have many different types of shrubs, ground covers, small trees and vines. They are also self-maintaining. A food forest is like a natural forest, but you choose the trees and all the other plants. It has many different layers and sizes of plants. It has canopy trees, tall trees, understory trees, vine, shrubs, ground covers and root plants, the same as a forest, but they are all productive plants which grow well in that situation.

Examples:

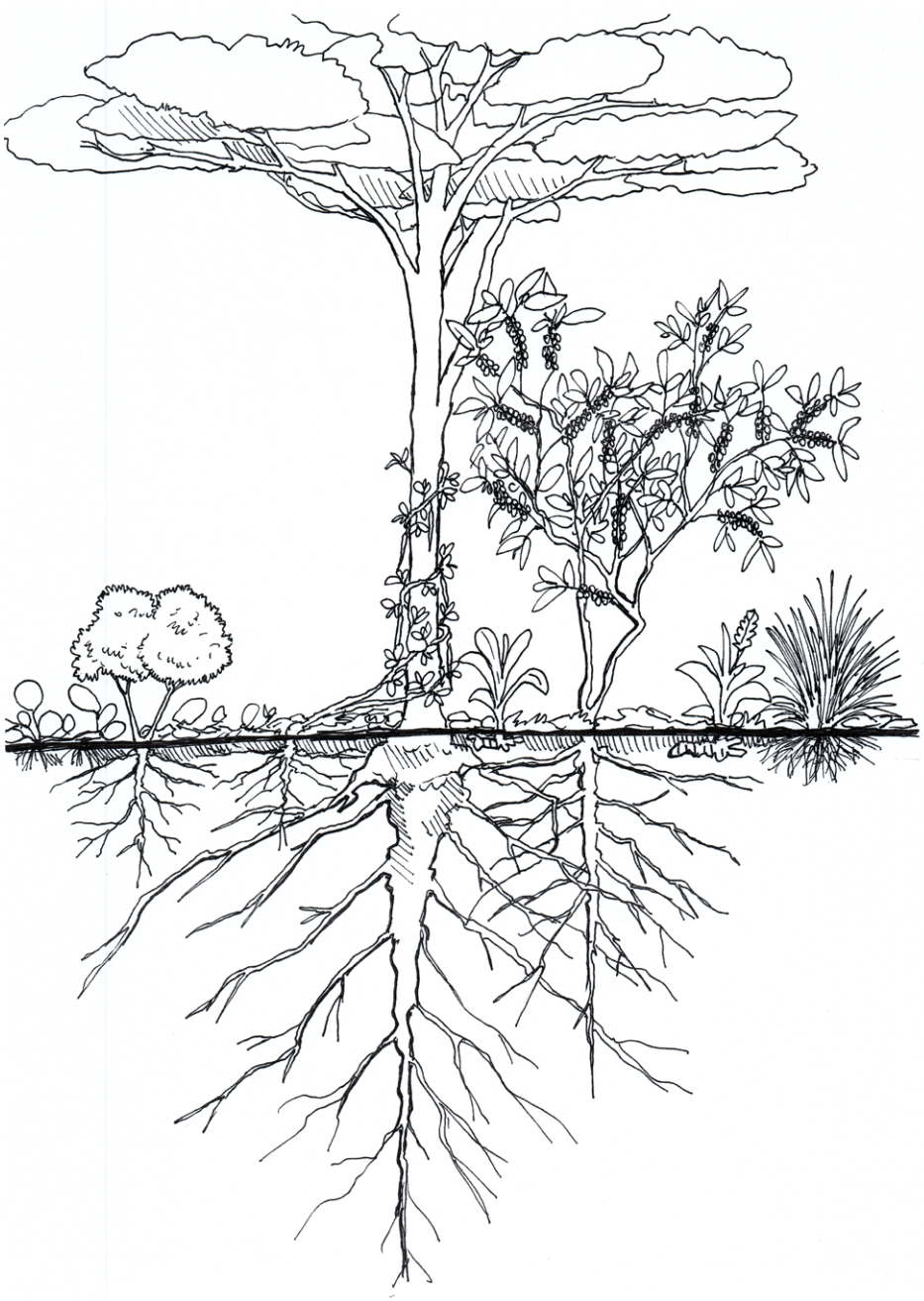
- Canopy and tall trees – *Tipuana tipu* (rosewood), albizia, jackfruit, coconut
- Understory – coffee, cacao
- Vines – vanilla, beans
- Shrubs – sweet leaf, cardamon
- Ground covers – gotu kola, mint
- Root plants – ginger, turmeric, galangal
- Other production – mushrooms, bees

A food forest also copies a natural ecosystem with the relationships between the plants, animals, birds, insects and soil. Because food forests are like natural ecosystems, they are much more resilient and able to cope with climate extremes.

Food forest stages

Creating a food forest is like copying natural reforestation. This speeds up the results and ensures the system is healthy.

1. Prepare the land (see previous section).
2. Plant legume tree pioneers and other pioneer plants. They grow quickly, improve the soil and create the best conditions for the next step. Some can be future canopy trees (e.g. *Tipuana tipu*), and some short-term small trees (e.g. pigeon pea).
3. Remove some of the smaller legume trees to plant canopy productive trees. It is smart to remove and replant in areas where legumes are growing the best, not where they are weakest. They are indicator plants that show where the best growing conditions are.
4. Plant canopy trees (fruit trees, nut trees, oil trees, medicine trees, timber trees, legume trees, etc.).
5. Plant understory trees. Some tougher varieties can be planted at the same time as the canopy trees, and some a year or two later when there is more protection for them (shrubs, small trees, bushes, vines, spices, ground covers, etc.).



Integrated orchard and agroforestry systems

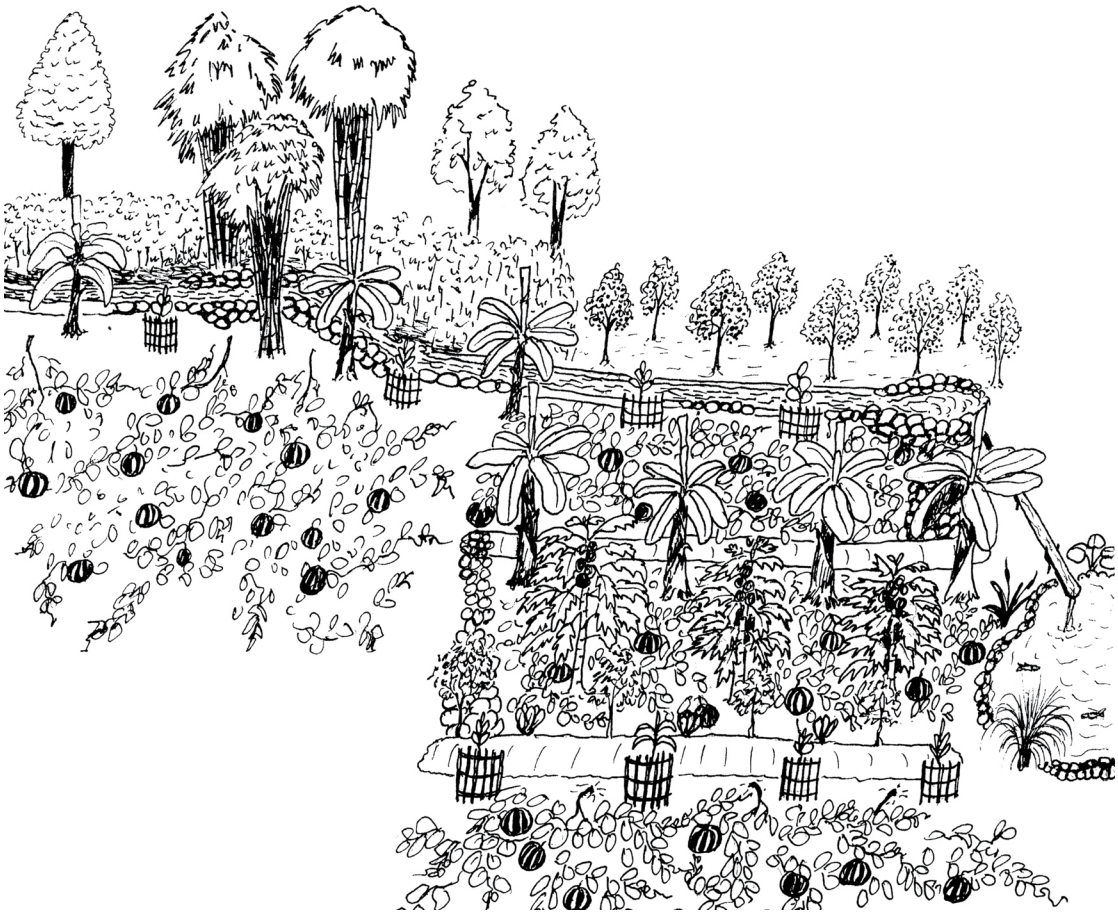
Develop a combination of productive trees, other agricultural crops and animals.

They are intensive systems that produce many different yields, and produce most of the resources needed for the system: e.g., manure, mulch, compost, weed and grass management, integrated pest management, fences, etc.

These systems still have different tree heights and trees types but also have open spaces for crops and animal grazing.

These systems work in all tropical regions; mountainous and coastal, flat and sloping, dry and wet areas.

A big benefit of this system is that in the tree sections, you can grow vegetables, grains, papayas and bananas to provide food and income while you wait for the large trees to grow and produce crops.

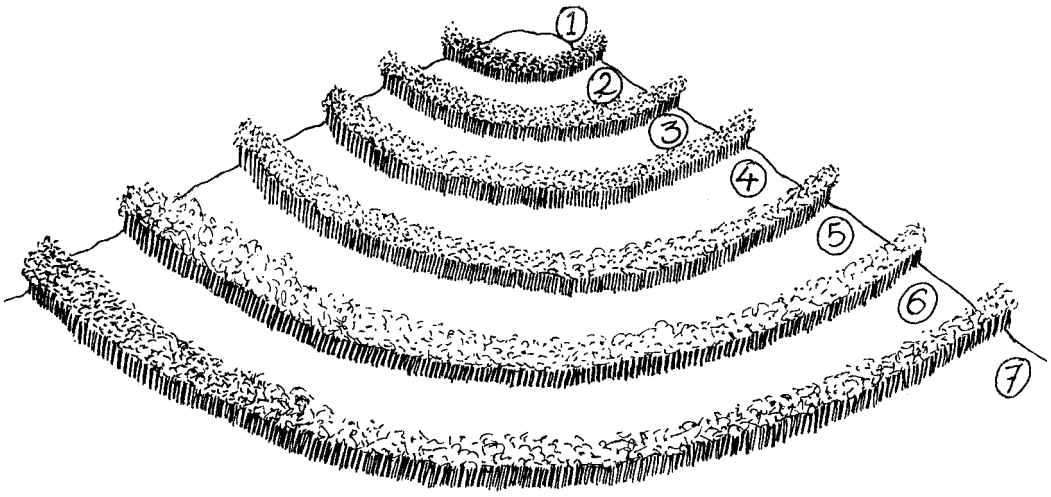


Designing the system

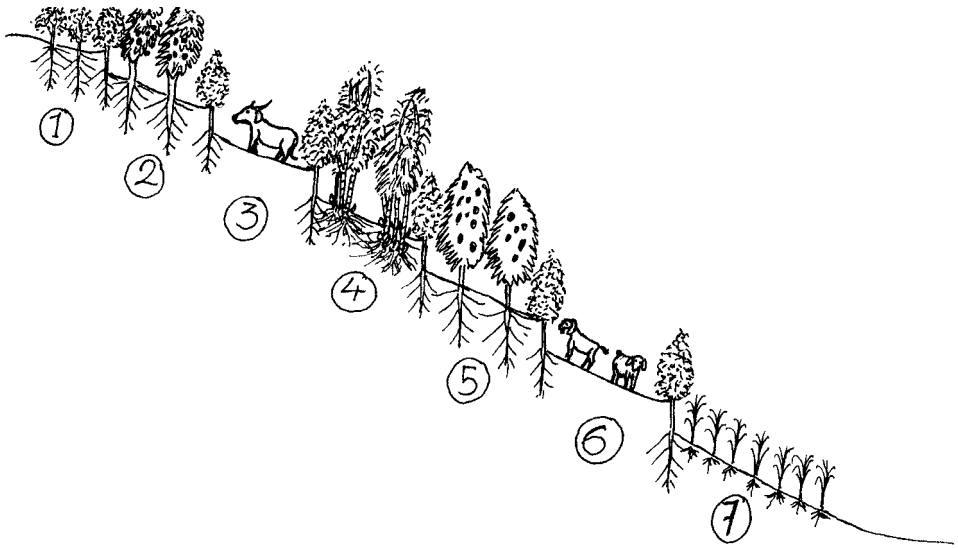
A good design for your system is essential, both for the short and long term. This includes land preparations, especially on sloping land.

For many systems, plant rows of legumes to divide the land into sections or "alleys". On sloping land plant these rows as tree terraces or below swale mounds. Prune them once every one to two months in the wet season, and put the branches around the tree and vegetable crops as mulch or feed them to your animals. The legume rows become living fences and eventually you can introduce animals.

In between the rows of legumes are large rows or "alleys" that can be used for many different crops. These crops could be different tree varieties, including fruits, nuts, timbers, spices, etc., as well as bamboo, vegetables, grains, corn, coffee or cacao with canopy shade trees.



Rows created by legume tree terraces



Cross section of rows used for tree crops, animal grazing and annual crops

Not all of the land needs to be used straight away. It is much better to have a few complete sections than lots of half-complete sections. The other sections can be planted with legume trees, green manure crops and possibly vegetable crops until you are ready. When the first rows (alleyways) are established you can work on the other rows.

IMPORTANT IDEAS:

- Base your design 30 years in the future! Create a map showing what your land will look like when the trees are fully mature. Then you can get the spacing between the trees right so that they are not planted too close together or too far apart. There will be spaces between the trees while they are young and small. You can grow small fruit trees, such as papayas and bananas, in the first few years until the tree crops become too large. Many different legumes can also fill the gaps, grow up faster and provide wind protection, mulch material and nitrogen.
- Grow shade-tolerant crops with the tree crops once they are tall: e.g. coffee, cacao, ginger, taro, vanilla.
- Plan your crops so that in the future tall trees do not block the sun to vegetable crops. Grow vegetable crops, such as pumpkins, melons, chilies and beans, from mounds between the trees.
- It is good to plant many different types of plants in each row but be careful not to plant trees that will grow too large and take all the sun, water and nutrients from other trees. Plant small trees together and large trees together.

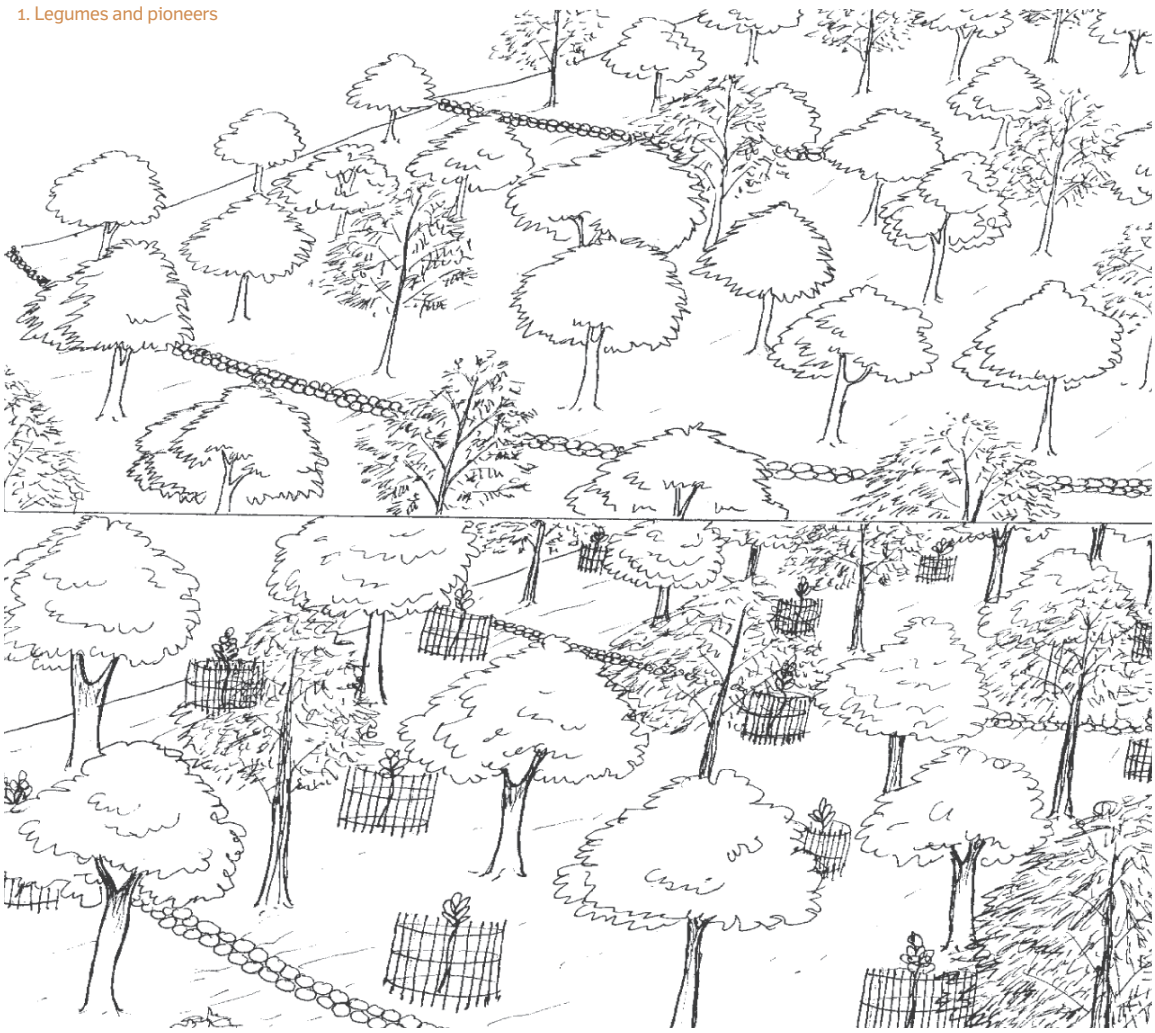
Trees of different heights that all require full sun need to separated to reach their full potential

Planting stages

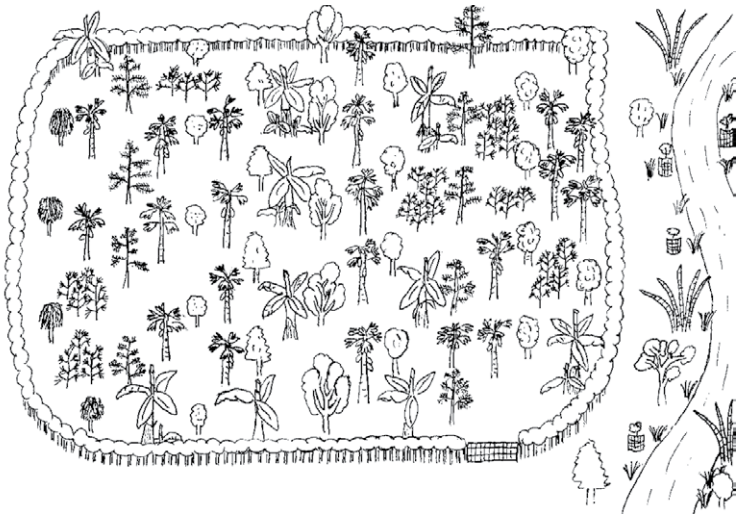
To plant the sections, use a similar process to food forest planting. Different steps occur as the trees develop. This seems as though it would take longer, but the end result of getting the trees to full production is actually quicker because the trees are healthier and grow in better conditions.

1. Plant legume trees. These grow fast so you cut them back and remove some later. If you choose to grow coffee or cacao, plant canopy trees too.
2. Removing some of the small legume trees provides space to plant the productive trees. As legumes are indicator plants – showing where the best growing conditions are – remove the ones which are the healthiest and plant the productive trees in the same place. The legumes greatly improve the soil, and provide mulch and fertiliser.
3. Plant fruit trees and other productive trees between the remaining legumes. The legumes provide some shade and protection for the young fruit trees. As the fruit trees grow, prune the legumes back to give space, and plant short-term producers such as papaya and banana. The large fruit trees will eventually take over.
4. You can introduce animals into the system once the trees are well established; small animals earlier than larger animals.
5. Grow understory plants, such as some herbs, spices and other shade-loving small plants, under the trees.

1. Legumes and pioneers

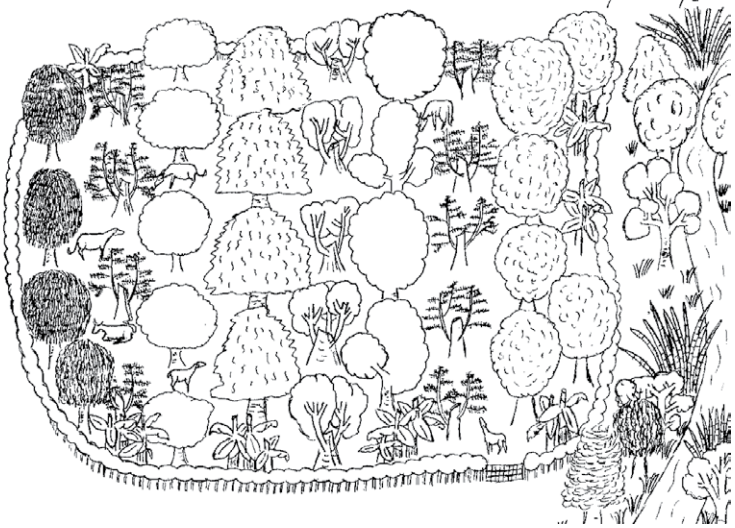


2. Planting fruit and timber trees



After two years

After five years



After ten years

This is a natural system that works with nature's principle of succession. If you work with this principle and use it for your benefit, the growth rate of the system and the trees is much faster and yields will improve.

Tree combinations

A mix of different tree crops and vegetable crops is best, integrated with animals. More diversity in trees, vegetables and animals means a much better range of food, products and a more stable income.

For soil with many rocks, for dry areas or for large amounts of land, plant more tree crops than vegetable crops. Trees require less maintenance and continue to produce crops in difficult conditions.

Here are a few different examples of crop integration that you can use:

LEGUMES TO PLANT AT THE BEGINNING

- Small trees/bushes: Pigeon pea, sesbania, gliricidia, caliandra and acacia and other trees such as moringa
- Annual legumes: Mung bean, pinto peanut, calopo, cow pea, desmodium, vigna spp., lablab bean, crotalaria and centrosema spp., clover (at high altitudes)
- Large trees: Inga spp, *tipuana tipu*, albizia spp

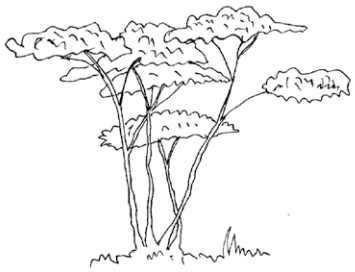
SMALL TREES WHICH GROW TOGETHER

- Citrus, banana, guava, custard apple, soursop, mulberry, papaya, sesbania, pigeon pea and moringa
- Spices, such as ginger, chili and turmeric, and vegetables, such as sweet potato, yam, cassava, bean and sweet leaf, can be grown with the small fruit trees.

LARGE FRUIT TREES WHICH GROW TOGETHER

- Mango, avocado, jackfruit, breadfruit, star apple, kapok, panama berry, durian, sapote, coconut, tamarind, bamboo
- When the trees are established, after four to five years, animals can be grazed through the system.

COFFEE AND CACAO PLANTATIONS



- Legume canopy trees: *Tipuana tipu*, *albizia*, *calliandra,* robinia, *Tamarix aphylla* (drought-, fire- and saline-resistant evergreen tree)
- Suitable hardwood canopy trees
- Coffee and cacao
- Smaller plants such as ginger, cardoman, vanilla, taro

LARGE PRODUCTION TREES

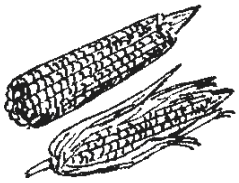
- Timber trees, oil trees, spice trees, bamboo, fibre trees, medicine trees, firewood trees and more can all be planted.

EACH REGION ALSO HAS ITS OWN HARDWOODS TO PLANT FOR THE FUTURE

Here are some examples, thanks to the *Ecoinvent Report No. 21, "Part 1: Life Cycle Inventory of Tropical Wood"*, 2007 [**www.ecoinvent.org**]:

- Africa: Iroko (African teak), Afara (Korina), Sapelli, Utile, Ayan, Ebony, Sipo, Okoumè (Gaboon), Moabi, Ayous, African mahogany (Khaya), Wengwe, Ozingo
- Asia: Ironwood, Amboyna, Kapur, Sepetir, White seraya, Jelutong, Ramin, Meranti varieties, Teak, Mahogany, Sandalwood
- Latin America: Mahogany, Virola, Balsa, Greenheart, Crabwood, Mora, Ekki, Brazil Nut

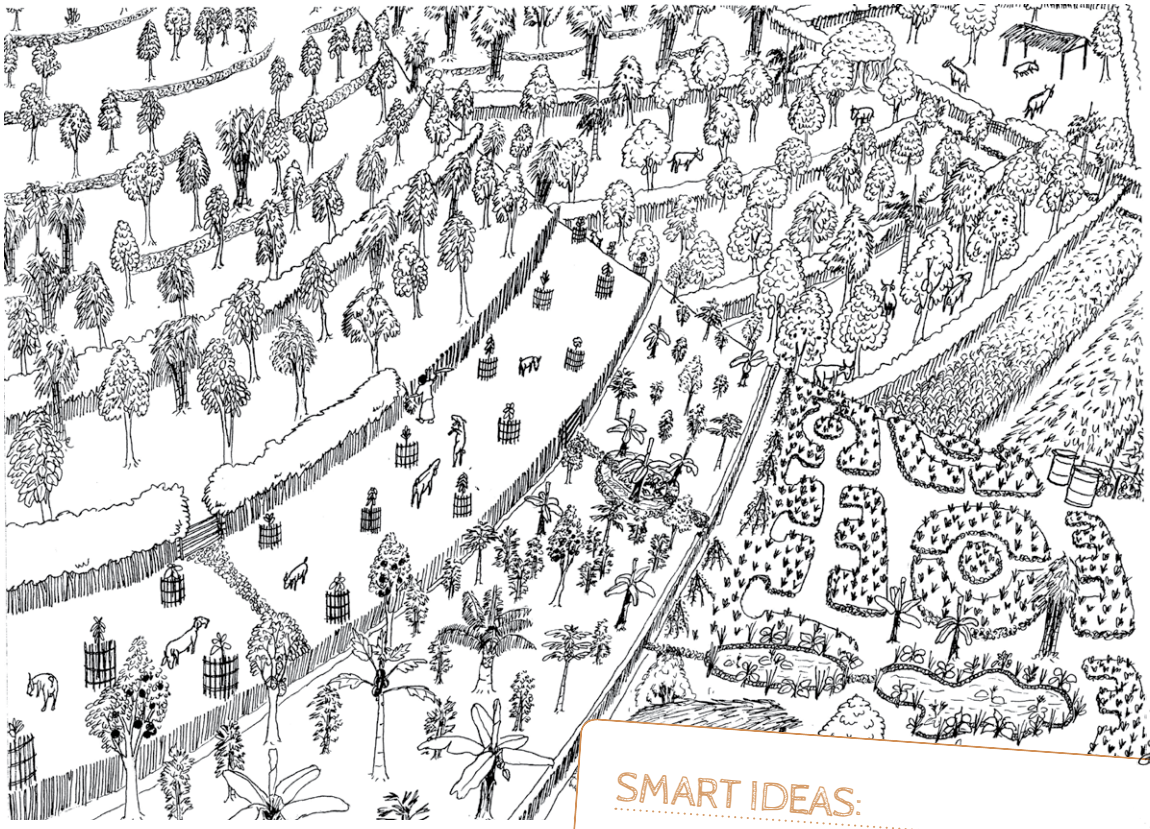
INTEGRATION WITH GRAINS AND VEGETABLES



- Sorghum, corn, sweet potato, cassava, bean, peanut, pumpkin, papaya and even banana can be grown when the trees are still young, or grown continuously in some of the sections.
- Smaller terraces can be established in the rows to increase the production for vegetables and small fruit trees such as pineapple, citrus, banana and papaya.
- Taro, water spinach, watercress and other water plants can be grown in the swale trenches in the wet season.
- Plants that like a lot of water, such as lemongrass, sweet leaf and arrowroot, can be grown on the edges of the trenches.
- The vegetable and grain crops benefit from the wind protection and nitrogen provided by the legume trees.

ANIMALS

- Once legume living fences are established, you can graze cows and buffalo in some rows.
- If goats are tied up, they can also graze in some rows.
- If you use animals in the system, you need to grow animal food trees to help supply a good diet. The legume living fences are good for animal food and you can plant animal medicine trees, too.
- Rotate chickens and ducks through the sections if they are carefully managed.



What you do and the combinations of different trees, vegetables, spices and animals you choose are up to you! Plan, design and create your system to suit your own climate, land and plants.

There are many more examples of flat land tree crops and integration with vegetable and grain crops in the Sustainable agriculture chapter (**Ch 13**).

SMART IDEAS:

- **Rotate crops** – Vegetable and annual crops need to be rotated to different plots each season for the best results. Growing different vegetables together also helps to keep your soil healthy.
- **Compost trenches** – Swale trenches can be used for making compost. Some nutrients soak into the ground from the compost and, when it is ready, spread it around the plants. Make compost pits, compost baskets and liquid compost wherever you need them. Nutrients used by the plants need to be replaced each season.

Fruit tree and tree crop maintenance

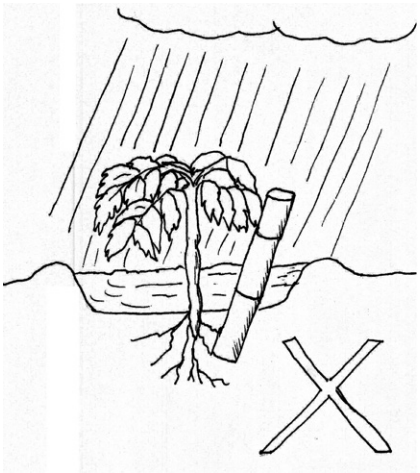
When selecting trees, make sure you grow or buy good quality trees! Choose seeds, cuttings or trees from parent trees that are high production, drought tolerant, highly pest/disease resistant and produce tasty food.

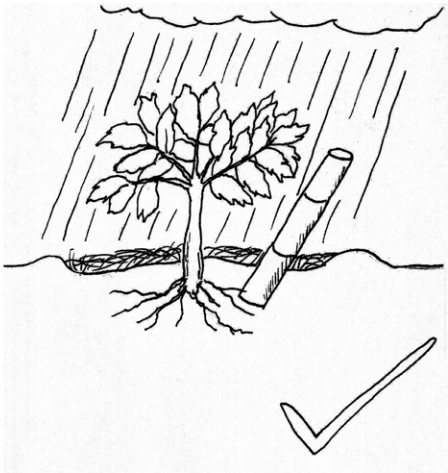
Planting

How you plant trees is very important! If you use good planting techniques and take care of them after you plant them, the trees will be healthier and grow much faster.

There are many different techniques, but the basic ideas are the same:

- Do not plant in the heat of the day. Late afternoon is the best time.
- The more water you give to the tree the better.
- Take care of the roots; disturb them as little as possible.
- Do not plant the tree below the level of the ground around it to prevent wet season flooding.





- Create a small "bowl" around the tree for water to collect and stay.
- Add a watering pipe if possible.
- Put lots of mulch around the tree.

Fruit and other trees that produce food or are part of a tree crop system benefit a lot from a little more work when planting.

WHEN TO PLANT

If you have a continuous water supply, plant fruit trees any time of the year. If not, plant them when the ground is wet and consistent rains have started.

A TECHNIQUE FOR PLANTING FRUIT TREES

Step 1: Dig a hole knee deep or more if possible. Fill the hole with water. Water the tree (still in its tree bag) at the same time.

Step 2: Put a bamboo watering pipe in the hole. Place some small rocks below the pipe to help water flow. Do not forget to break through the layers inside the bamboo pipe or the water takes a long, long time to reach the soil!

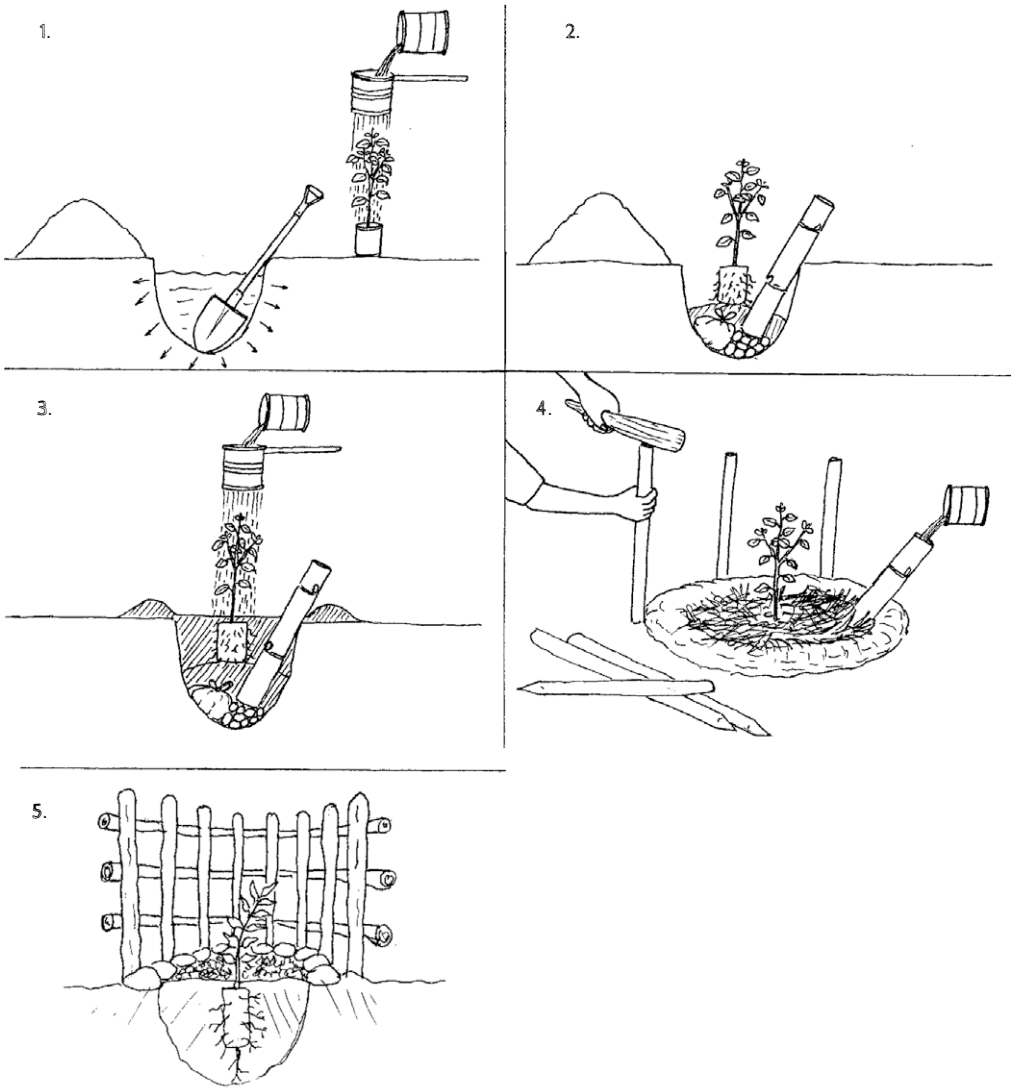
Step 3: Fill a 10 litre bucket with animal manure then place the manure at the bottom of the hole. Cover the manure with soil and make a small mound for the tree to sit on. For citrus trees and bamboo, do not put the manure in the hole but on top, under the mulch.

Step 4: **Gently** remove the tree from its container, taking care not to break the roots. If there are many roots, gently loosen those at the bottom of the tree. Place the tree in the hole, and make sure that the roots point down.

Step 5: Fill the hole with soil. Make a shallow bowl at the surface to collect water and help watering. Make sure that the top of the tree roots are covered with at least 2 cm of soil to stop the roots from drying out.

Step 6: Put lots of mulch around the tree, without touching the tree trunk. If you have compost put 2-3cm around the tree first, then add mulch on top.

Step 7: Water the tree.



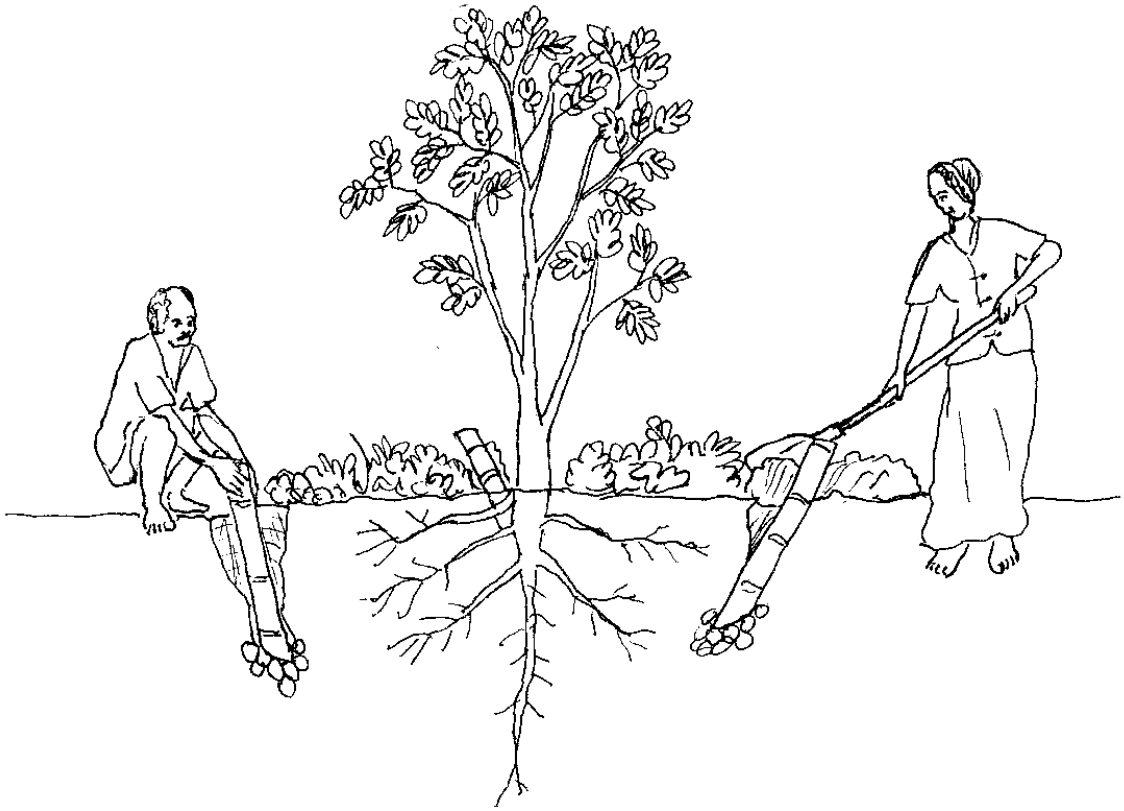
Fencing and tree guards

All trees must be protected from hungry animals, either with a strong tree guard for each tree or a fence around a group of trees. What you choose depends on your situation. Good community awareness and cooperation are important too.

Watering

Fruit trees and tree crops must be watered in the dry season if you want good production and large fruit, especially for the first few years.

- It is **much** better to give a lot of water once a week than a small amount every day or two. This encourages the roots to grow down looking for water and, therefore, they reach the ground water much faster.
- Use the bamboo watering pipes.
- Water late in the afternoon or early in the morning.



Adding new bamboo pipes for water and liquid compost

Fertilising

Trees use nutrients from the ground as they grow and as they produce fruit, nuts and seeds.

Therefore, you need to replace the nutrients each year for the trees to be healthy and to produce good crops. It is the same for people and animals but, luckily for us, we do not need to feed the trees every day.

Fruit trees grow best if they are fed from a variety of sources and are in healthy living soil.

Compost, liquid compost, manure, seaweed and mulch provide a wide range of nutrients and also improve the soil.

Look in the Soil chapter (**Ch 9**) for techniques to make and use all of the fertilising methods listed here.

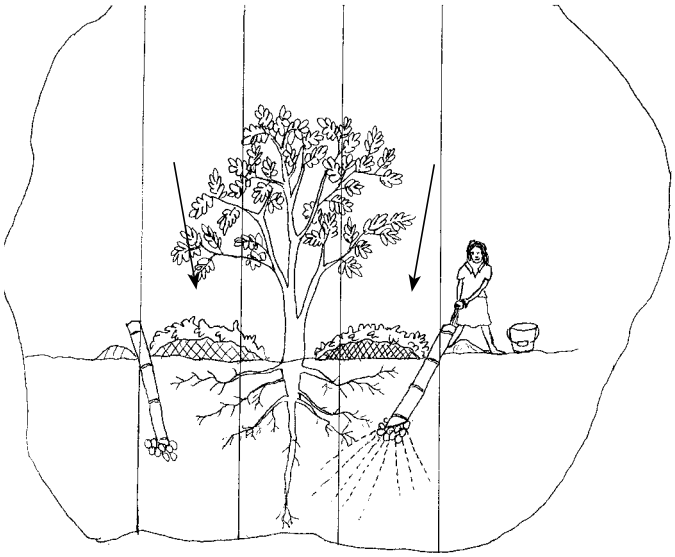
Liquid compost

Where, when and how much to fertilise?

Underneath the outside leaves of each tree is a circle called the "root-feeding zone". This is where the outside roots of the tree grow the fastest and are most efficient at gathering the nutrients the tree needs. Add your fertiliser here.

A small mound circle made just out from the outside leaves improves watering and fertilising results. Move this mound circle outwards as the tree grows.

For young trees, use a bamboo watering pipe to feed liquid compost directly to the tree roots in the ground.



Best area to fertilise, mulch and water trees

Compost and manure

Apply compost and manure mostly around the "root-feeding zone". Apply them twice a year; just before the flowering cycle starts and when the fruit is half ripe. A layer of 5cm provides plenty of nutrients. Cover the compost with mulch.

Direct composting is a compost rotation technique explained in Soil (**Ch 9**). When compost is made over the "root-feeding zone" of a mature fruit tree, nutrients from the compost continuously enter the soil and feed the fruit tree. When it is ready, spread the compost around that tree and others, and start a new compost pile under a different tree.

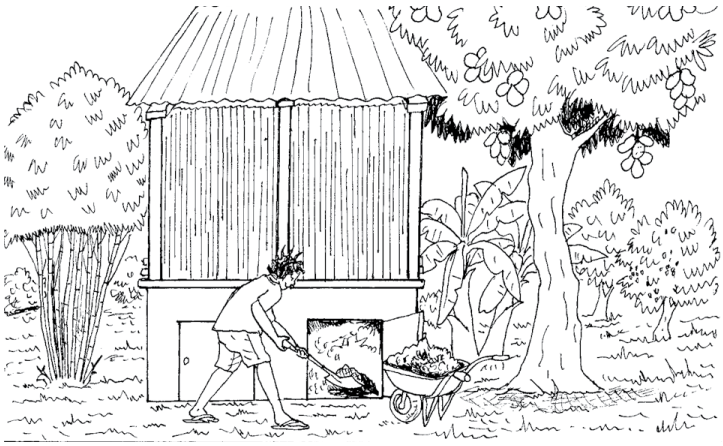
Growing fruit trees using direct composting, liquid compost and living mulch fertilising techniques

Liquid compost

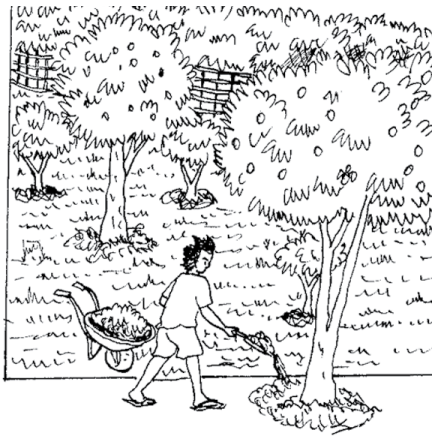
Put half the liquid compost in the bamboo watering pipe and half around the "root-feeding zone". Apply it every two months in the wet season and once in the middle of the dry season. For young trees up to three years old, use a large (20 litre) bucket. For older trees use up to three large buckets. Always mix the liquid compost with water at 1:10 or 100ml of liquid compost for every litre of water.

Humanure fertilisers

Diluted urine is an excellent, continuous source of natural fertiliser. It contains a lot of nitrogen. Citrus trees especially like diluted urine fertiliser. Give it to a different tree each time but not too much for young trees. Compost from compost toilets is great to use around fruit trees, spread in the same way as other composts and always put mulch on top.



1. Removing composted manure from compost toilet.



2. Spreading compost manure around fruit trees

Green manure crops

Green manure crops are excellent fertilisers, soil improvers and erosion control around fruit trees in the wet season. Mung beans, lablab beans, pinto peanuts and clovers (all legumes) are examples of good plants to grow. Wait until regular rains have started.

1. Soak the seeds in water overnight. Add a few tablespoons of liquid compost, if you have any.
2. Scatter the seeds around the root-feeding zones of your fruit trees. Rake them into the ground so that most of them are lightly covered with soil.
3. Cover the area with mulch and watch them grow!

There are several options for what you can do for the next step:

- Cut the crop back when it begins to flower and use the tops as more mulch. This provides the most nitrogen for the fruit trees. Leave some plants to go to seed for the next crop.
- Cut the crop back when it begins to flower and feed the tops to your animals, again leaving some to seed for next year. Or let your chickens and ducks into the area to feed on the tops.
- Leave the whole crop to seed. This gives you a crop and you can still chop the stalks down to provide mulch and root biomass, but you will not give as much nitrogen to the trees.
- Grow pinto peanuts or clovers – which live for much longer than beans – and twice a year cover them with mulch. They die off and release nitrogen, then grow back again later.

Living mulch plants

Sword beans, velvet beans, pumpkins and gourds are great to grow if you create a growing mound for them that is outside the root-feeding zones of the fruit trees. They cover the ground and improve the soil while also providing you with food and produce. Fertilise and mulch the growing mound for good results. Plant the mulch crop when regular rains have started. Other legumes, such as centrosema and cow pea, are also good.

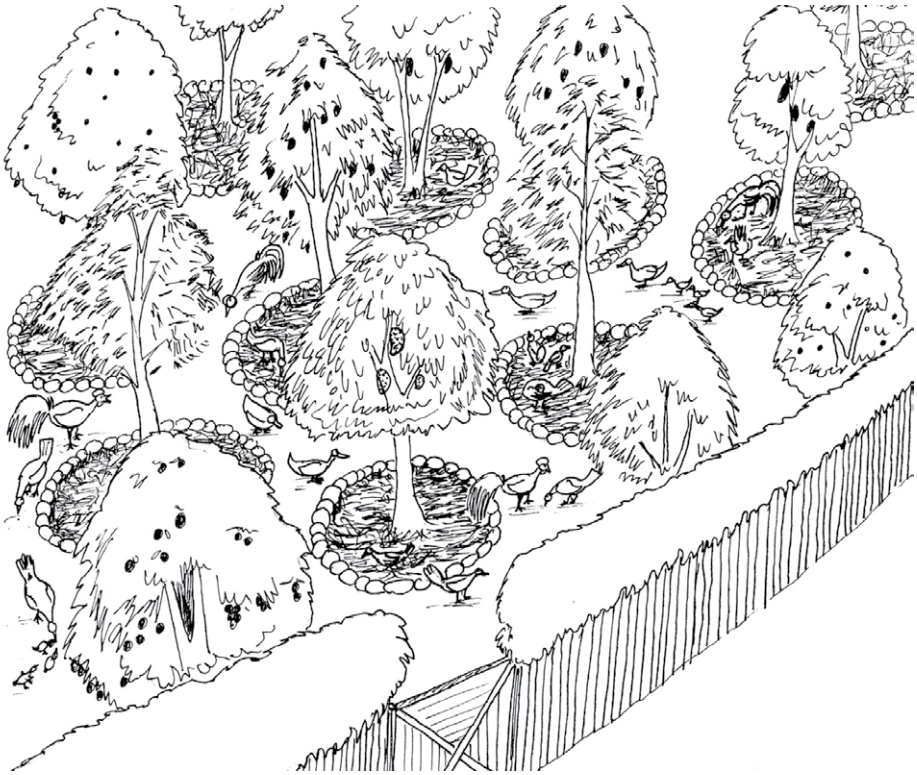
Mulching

Mulch around a tree is a very important part of tree maintenance.

It provides many benefits:

- Water stays in the ground and does not wash away. The wet season is extended because the ground stays wetter for longer.
- Mulch should be placed on top of manure and compost to maximise their benefits.
- Mulch is an important source of nutrients for trees and provides a lot of the nutrients they need.
- Mulch improves the soil quickly by increasing the organic matter and biota in the soil.

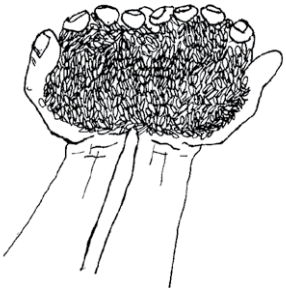
Apply the mulch from the just outside the root-feeding zone to near the trunk of the tree. Mulch or seaweed should not touch the trunk as this could cause a disease or a fungus which damages the tree. Leave a 10cm gap around the trunk. Apply the mulch continuously as a layer up to 10cm thick. A thick layer is important so that the mulch works properly to keep the ground moist and quickly improve the soil.



Rock circles hold the mulch in

DIFFERENT TYPES OF MULCH

- Cut and dried grasses
- Dried rice husks and coffee husks
- Seaweed – collect it fresh and wash it before using it to reduce the salt content.
- Dried tree leaves, cuttings from legumes and dried weeds
- Rocks, old paper and boxes, rotten wood and bamboo, banana leaves and stalks and any other natural materials also make good mulch and supplement the other mulch, compost and dried manure.



Soil improvers: biochar and bacterial activators

These techniques - biochar and bacterial activators are great for fruit trees, agroforestry and integrated tree crop systems because you can apply them once and they work for years, and their benefits multiply!

Biochar (activated charcoal) is charcoal that is produced using a low oxygen burning system. It is cheap, can be produced on a small or large scale and is very sustainable, especially when you use bamboo. The charcoal produced is soaked in liquid compost full of good soil bacteria for a few days before use.

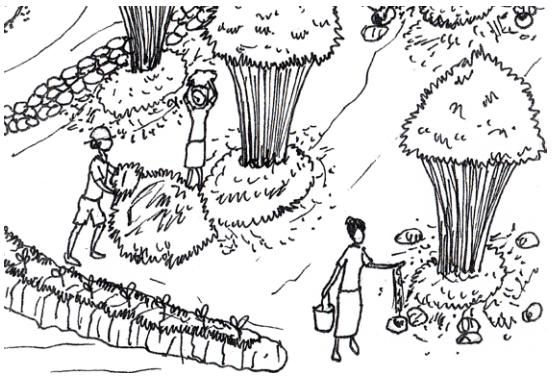
Soaking biochar in micro-organism rich liquid compost before use

Dig in half to a bucket of biochar around each fruit tree; a bucket for each tree, if you have enough. The charcoal slowly adds carbon to the soil and lasts for many years. The charcoal acts as a home for nutrients and bacteria and holds them in the soil, especially in the wet season. This means that your soil continuously improves and the organic fertiliser you add is completely used by the trees and not washed away.

Bacterial activators are another method of putting the right micro-organisms and biota in the soil. They are especially good when planting in a new area or repairing degraded soils. They aid continual soil improvement, spreading and multiplying as long as you feed them with organic materials, but do not use chemicals. Use activators to improve large areas of land quickly and maximise the benefits of compost, manure and mulch.

To apply the activators divide the land into rows three metres apart and in each row dig a small hole every three metres. Try to create a zig-zag pattern. Pour approximately 200ml of bacterial activator mixed with 800 ml water into each hole, and fill it in. Cover the patch immediately with compost or manure, if you have it, and mulch.

Look in the Soil chapter (**Ch 9**) for techniques to make and use all biochar and bacterial activators.



Adding biochar and bacterial activators around fruit trees and bamboo

Weed control

Weeds reduce production and growth by competing for water and nutrients, and they make tree maintenance more difficult. However, not all weeds are bad, and different weeds need different treatments.

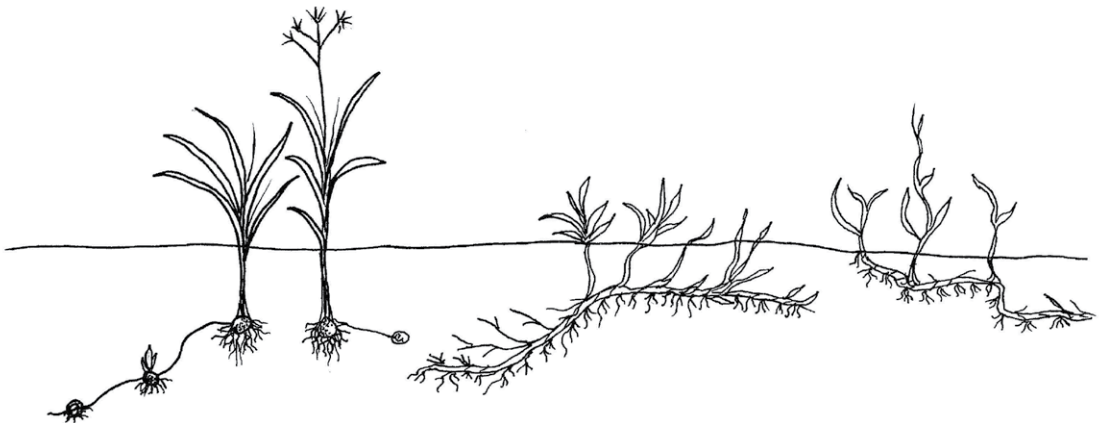
Weeds that can be useful are:

- Annual grasses and bushes
- Weeds that can be animal food
- Legume weeds
- Weeds that grow quickly and produce a lot of biomass for mulch and compost
- Weeds that only spread by seed are less of a problem if there is a management plan.

Collecting nutrient rich water weeds to use as mulch around fruit trees

Weeds that require careful treatment and removal:

- Grasses that run and spread underground, and bulb weeds that spread quickly
- Perennial clumping grasses and bushes
- Weeds that are poisonous to animals or people

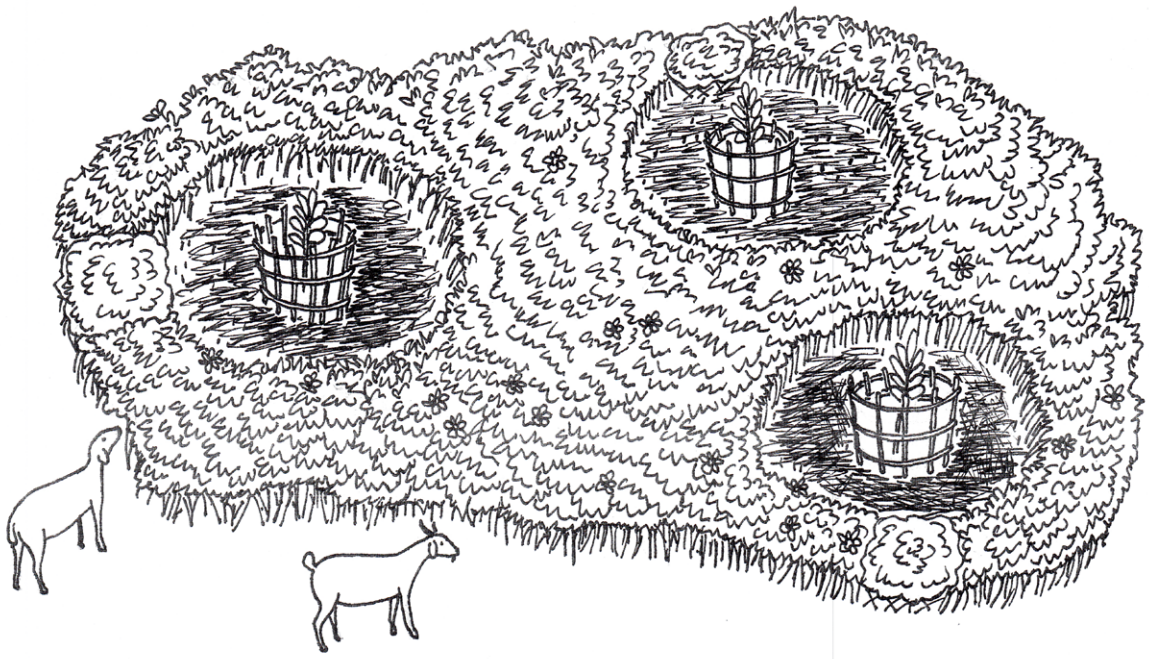


Nut grass, kykuyu and couch grass require careful treatment and removal

STEPS FOR WEED CONTROL

1. Identify the weeds.
2. Create a long-term weed management plan with yearly steps to achieve. This might include stronger, careful measures to remove weeds for the first year or two, but it should always result in self-managing, sustainable and organic systems. ONLY remove weeds from areas that you can immediately replant with the desired plants, otherwise new weeds will grow.
3. Use appropriate control methods for the weeds you have and make use of them:
   - Animals are excellent weed controllers in a well-managed system.
   - Mulch and cover crops reduce or prevent weed growth.

Do not burn the weeds! Burning weeds damages the soil, causes erosion and wastes valuable mulch and compost materials.



Using weeds like Tithonia diversifolia to protect and provide mulch and fertiliser for new fruit trees.

SMART IDEAS:

- Select the best weeds to promote and allow them to grow. They reduce and outcompete worse weeds, and produce a lot of biomass for mulch and compost. Slowly remove them as long-term planned tree crops take over. Some can be kept in the system as part of long-term land management and animal food production plans.
- Citrus trees have shallow feeder roots and do not like much competition. They require more careful weed management to ensure good production.

Pruning

Pruning trees is necessary for maintaining tree health and productivity.

Diseases and fungi can spread easily if trees are not pruned. Harvesting is much easier as well because trees are lower to the ground and easier to access.

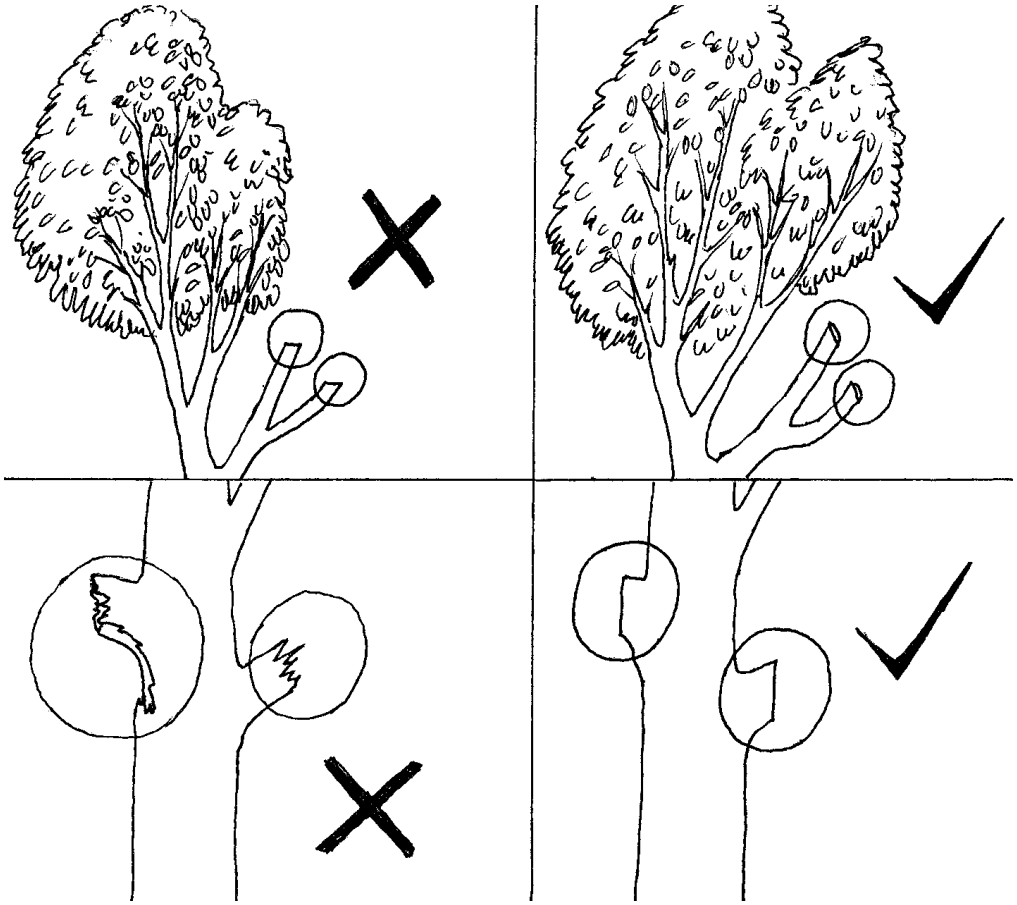
HOW TO PRUNE A BRANCH

Using the right technique is VERY important because the tree grows back much faster, suffers less stress and is much less likely to suffer from diseases or fungi.

Step 1: Use a saw, if possible, a very sharp knife or machete to prune.

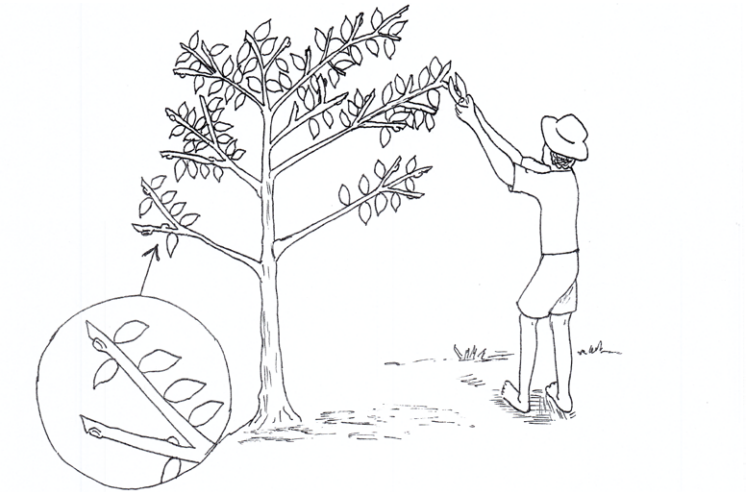
Step 2: Prune the branch as close to the next main branch as possible. Make the cut as smooth as possible. Make it angled or up and down but not flat (horizontal). A flat cut increases the chance of disease.

Step 3: For fruit and other important trees you can paint a layer of jackfruit tree sap or neem tree sap on the cut. (Sap is the thick liquid collected when the tree trunk is cut.) This stops diseases or fungi from entering the cut.

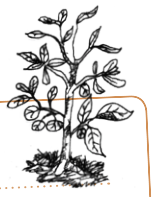


PRUNING FOR GOOD PRODUCTION

For most tropical fruit trees, if you create a good tree shape when the trees are young, you get better production and will not have to prune much when the trees are older. Start when they are a metre or so high by removing the tips of branches at the beginning of the wet season, when trees are beginning to shoot. Cut down to the first bud that is facing outwards. This encourages the tree to develop an open shape and reduces their height. Strategic pruning encourages new growth and maximises airflow and sunlight. After pruning always fertilise and apply mulch.

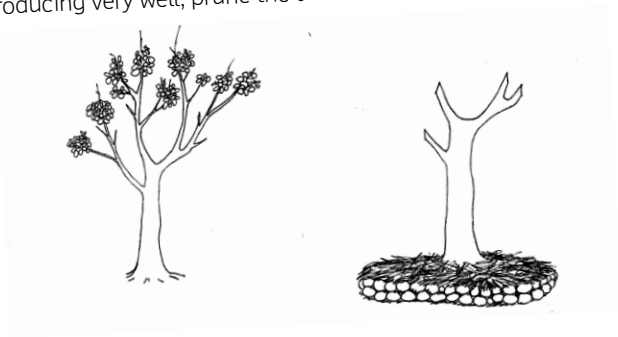


When the tree is mature, pruning should only be needed to thin out and remove dead or diseased wood. Cut the branches lower than where the diseased or dead wood begins. This should be done once a year or as necessary. Any diseased branches that are pruned must be taken away and burnt to stop the disease from spreading.



SMART IDEA:

To encourage new growth and better fruiting on older trees that are not producing very well, prune the tree back to the basic frame.



PRUNING LEGUMES

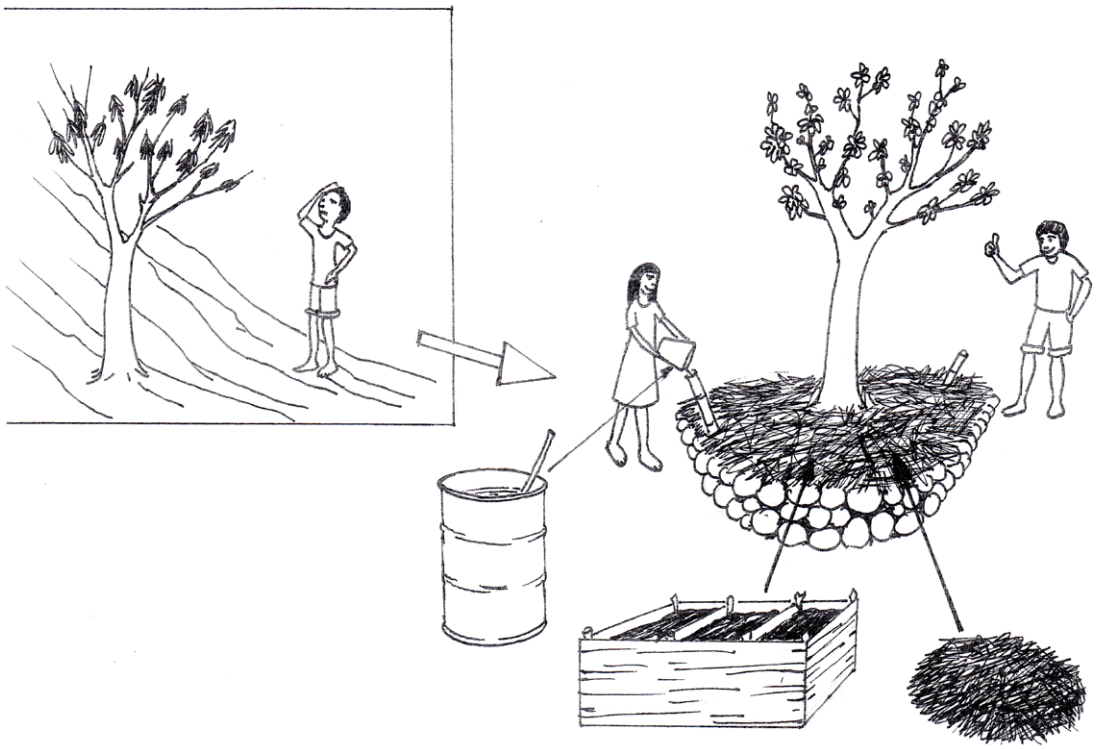
It is important to prune regularly legume trees that are grown for mulch, soil repair or as living fences. By pruning legume trees you put nitrogen back into the soil. Look in the Soil chapter (**Ch 9**) for more information. Prune them back to waist height for easy management, and prune the whole tree evenly for the best results.

REVIVING SICK AND UNPRODUCTIVE FRUIT TREES

Sick and unproductive fruit trees can quickly regain health and produce lots of fruit within a year or two. The MOST important steps are to create a healthy environment for the tree: it is usually this problem that creates a weak tree, which can then be attacked by pests and fungi.

Some solutions are:

- Build a slow compost pile next to the tree.
- Add lots of mulch.
- Create a garden border to build up soil.
- Add a bamboo watering pipe or two for deep watering.
- Apply liquid compost for an immediate nutrient supply.
- Remove all the dead branches and/or prune the tree to let air through the branches if they are too thick.
- Create water catchments if the land is sloping.
- Treat any pests or diseases with a natural pesticide or fungicide (this only works if you follow the other solutions too).



Reforestation

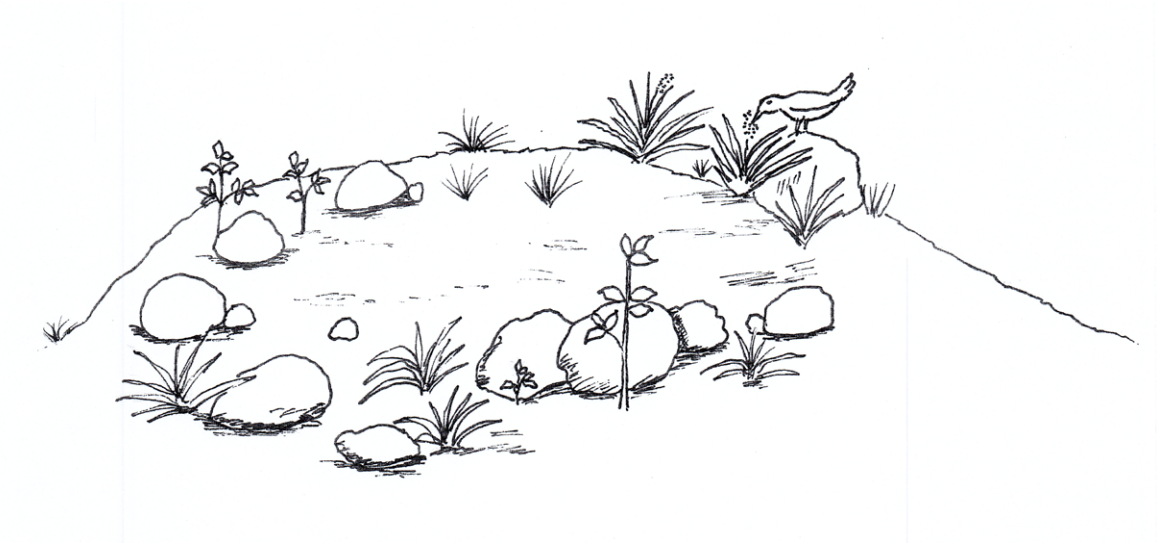
Reforestation is the planting of (mostly) local native trees with the aim of restoring forests.

They are less intensive systems than integrated orchard, agroforestry or food forest systems but they can still provide many essential products, such as bamboo, nuts, oils, fibre, timber, firewood, fruit and medicine.

Reforestation is very important for:

- Preserving the environment
- Protecting the water supply
- Stopping erosion
- Providing bird and animal habitats
- Reducing the strength of climate change and its negative impacts

Protection for the trees from animals, fire, wind and erosion is essential.
Read further in this chapter for techniques.



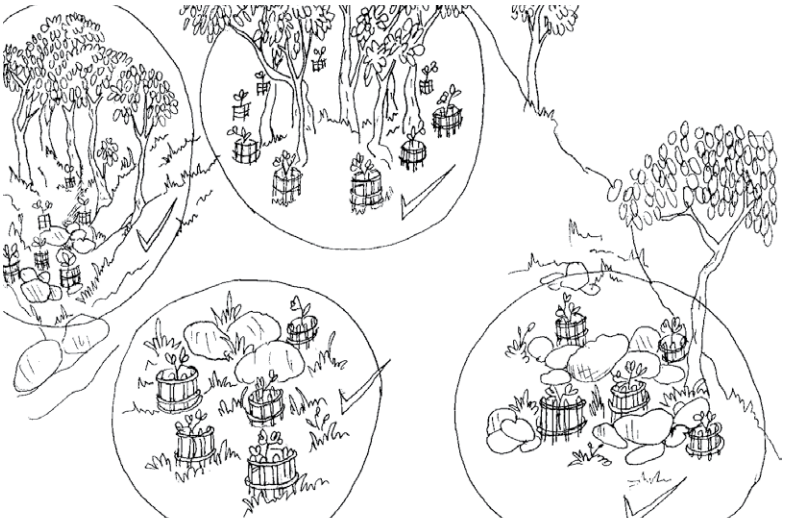
Choosing trees and plants

Successful reforestation starts with choosing the right trees! It is recommended you choose a variety of local native species. Elders, government agricultural workers and local environmental groups are great sources of information on what to plant and which plants used to grow in a particular place. If possible, collect the seeds to grow from strong, healthy trees in the area. The types of trees you choose also depend on where you plant:

- Ridges
- Steep slopes
- Dry creeks and small valleys
- Plains
- Floodplain areas

Choose a range of pioneers, canopy trees and shrubs and create a planting plan that copies a **natural forest to speed up results and ensure success.**

1. Plant grasses, legumes and some tough canopy trees.
2. Maintain established plants and trees, and plant more canopy species.
3. Plant and maintain understory trees and plants.



First planting, choosing naturally good areas to start reforestation

Next planting, using the established first trees to protect the new trees

Sometimes there is the opportunity to collect tree seedlings that have germinated under mature trees and transplant them. This technique is very successful if you:

- Collect them from healthy, strong trees.
- Collect them at the right age – one to two years old is best.
- Collect them at the right time – once the rains have started and the soil is easier to dig. This greatly reduces plant stress and root loss.
- Replant them straight away into the ground or into pots to grow up for later planting.
- Plant them in an appropriate location.

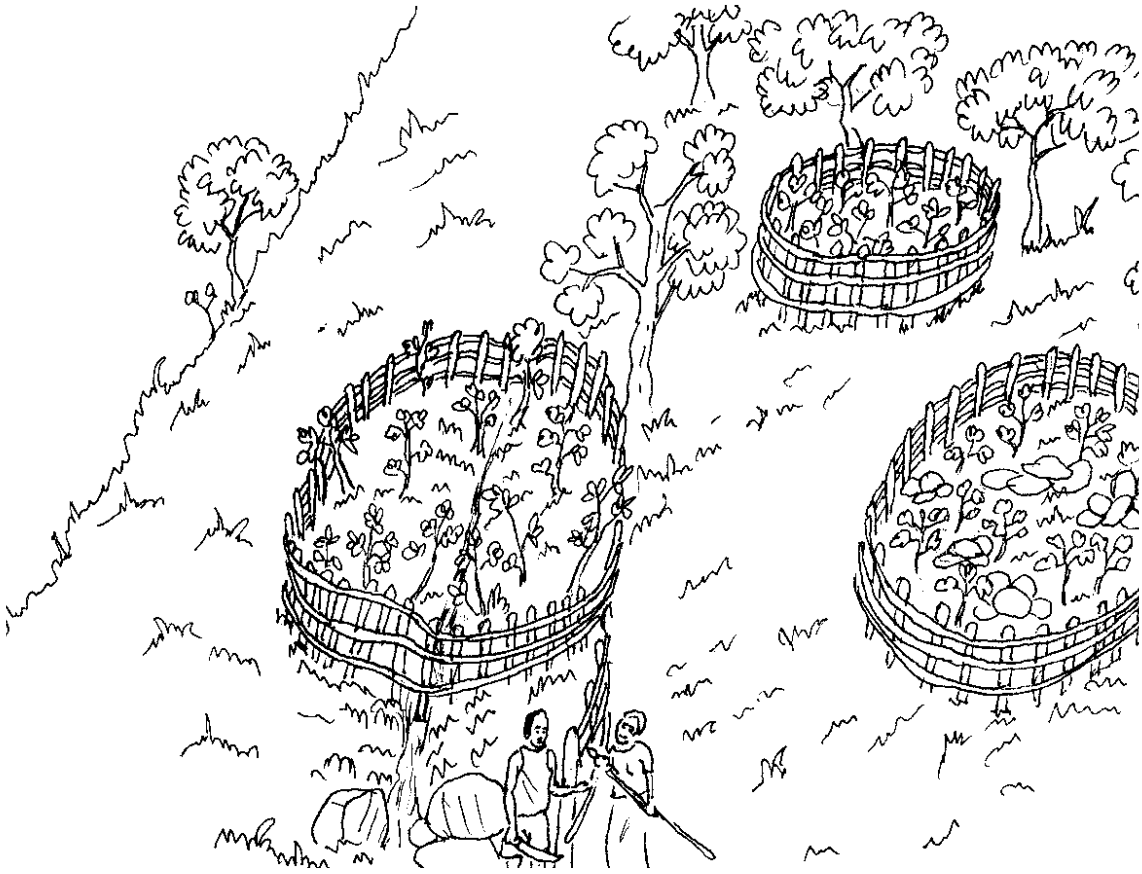
Site selection

Through observation identify areas on your land that are naturally good microclimates for plants and trees.

These areas are the best places to start reforestation. If you plant trees in these areas first, you improve your success rates and the trees grow better.

What to look for:

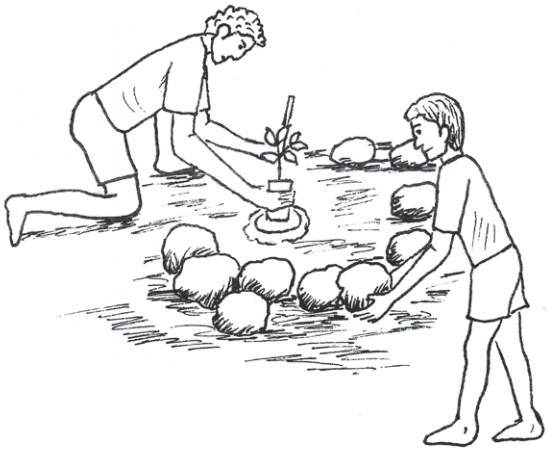
1. An existing group of trees. The trees grow in a particular spot because the microclimate is better. The existing trees also provide mulch, shade and wind protection for young trees.
2. Areas that have grasses and small plants rather than areas without. In very dry areas with few trees, the grasses and small plants indicate that there is better soil and possibly more water available. Plant trees in these areas first because the trees have a much better chance of growing. Areas with few or no grasses and plants show that there is poor soil, probably a lot of rocks underneath and not much water.
3. Large rocks or groups of rocks. If you plant below the rocks, the trees will receive more water from the run-off from the rocks. This can be improved even more by catching and storing the extra water.
4. Areas that water naturally runs to and collects in
5. For the southern hemisphere: The northern side of a mountain is the best side to start reforestation. This is because it gets a good amount of sunlight and has a better climate for plant growth. The southern side receives the least amount of direct sunlight. If it is very steep, it only gets a small amount of direct sun so try growing plants that like shade. For the northern hemisphere the reverse is true. For both hemispheres the western side is the hottest because it receives the hot afternoon sun.

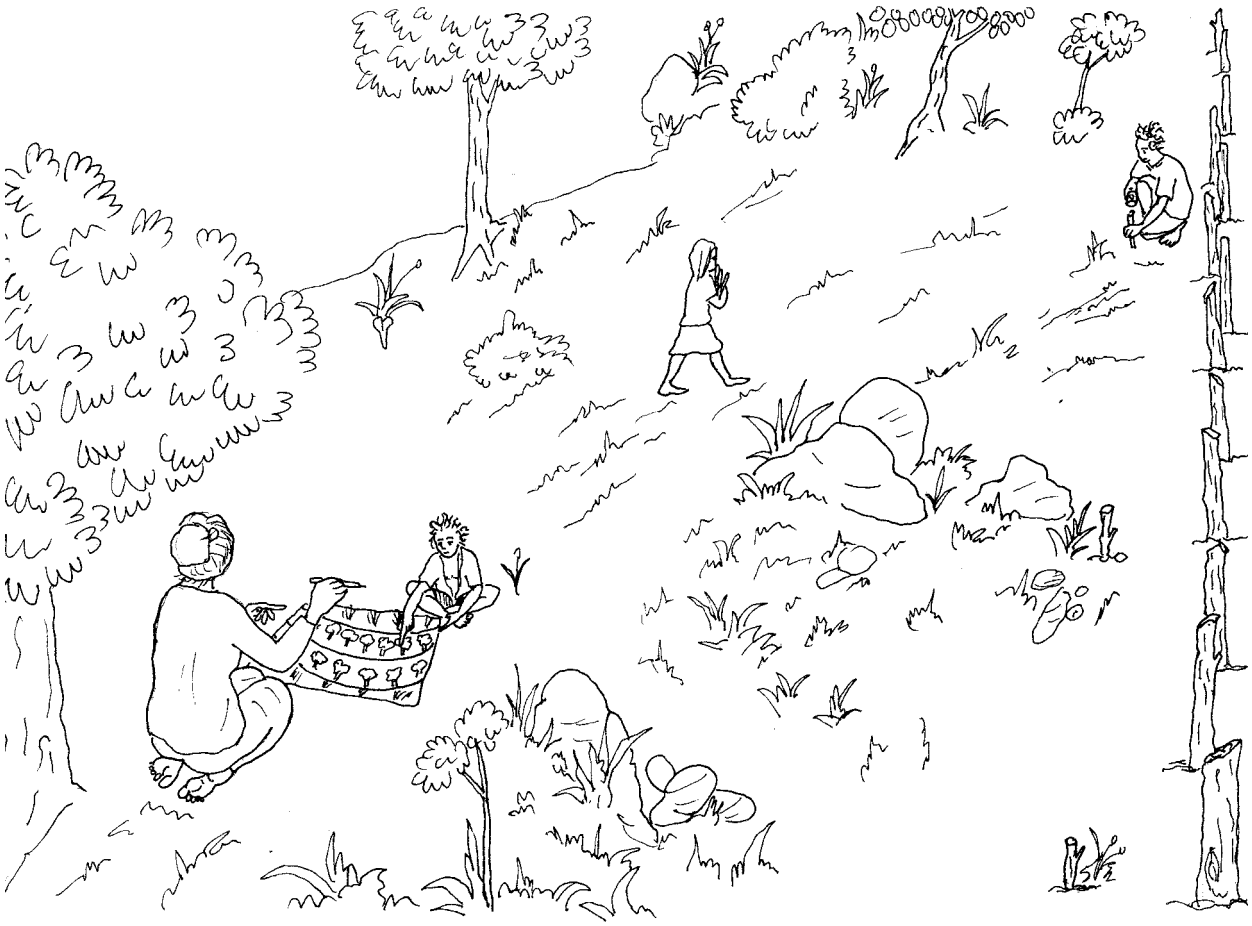


The fenced areas are naturally good sites for reforestation

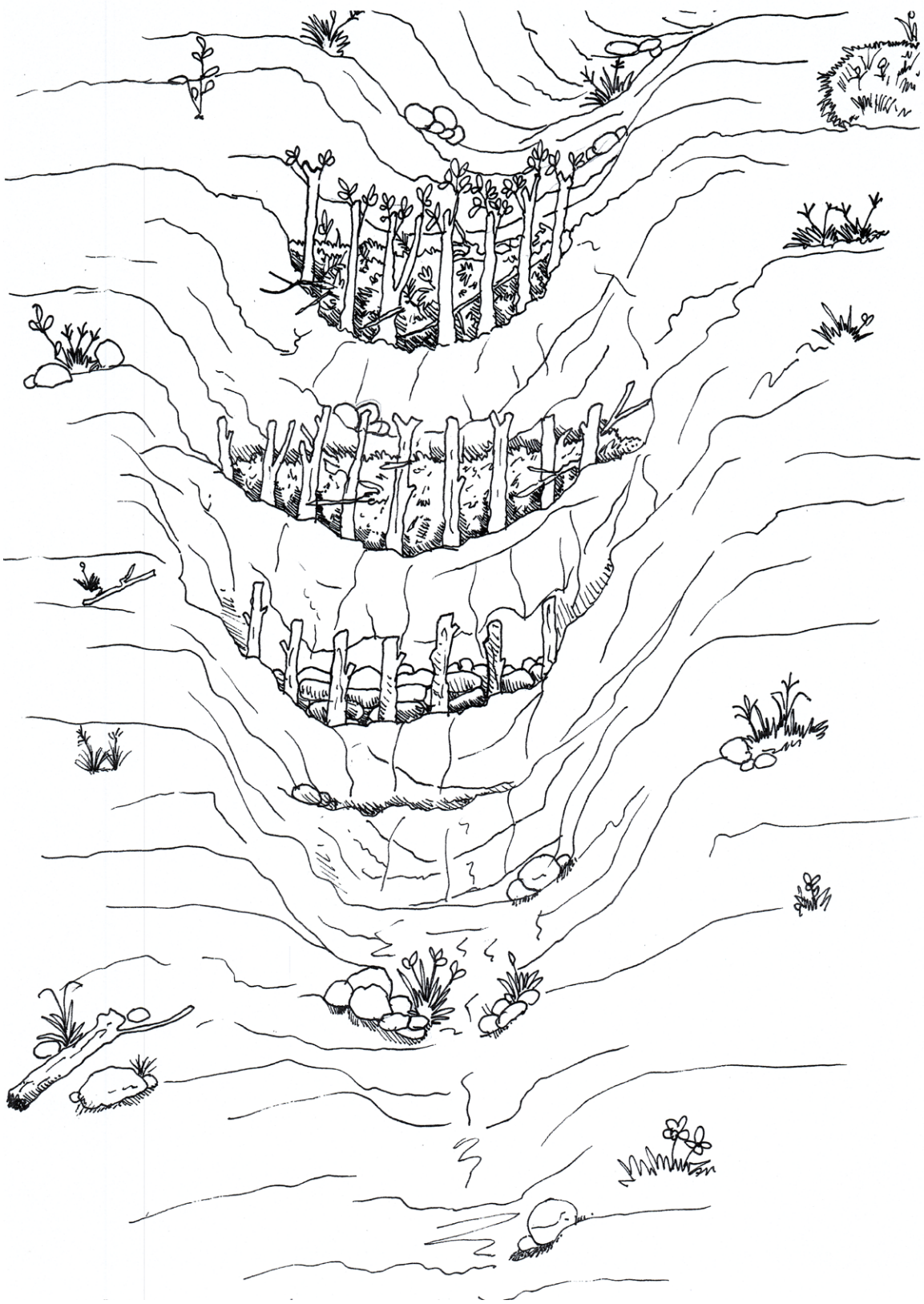
Site preparation

Boomerang swales, rock swales and other catchment techniques all improve success rates by securing and collecting soil, leaves and rain. Even a small pile of well-placed rocks and/or rotten logs help and could be the difference between a tree living or dying.





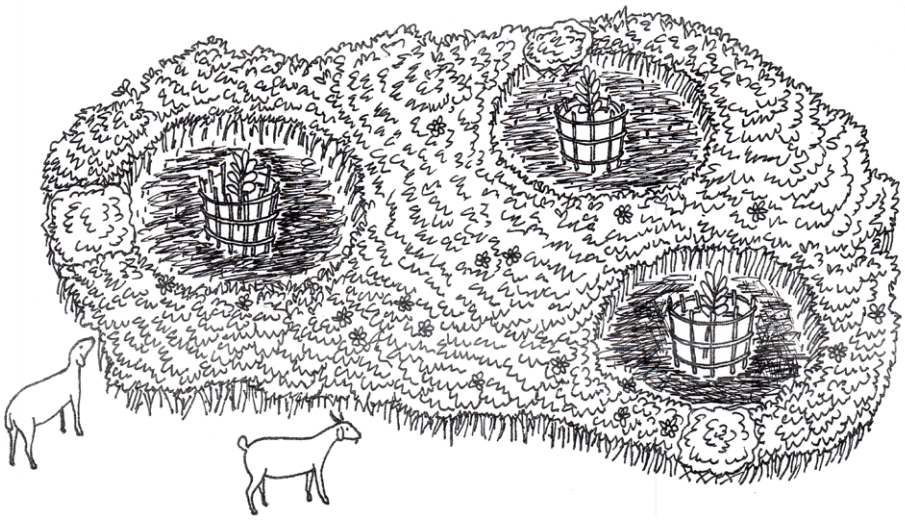
For small valleys and dry creeks, put in living stakes, dead wood stakes and bamboo stakes to create a barrier for slowing water and catching all the leaves and materials, and you quickly start the reforestation process and reduce erosion. Combine this with rocks too. It can also work for bigger gullies but be careful of large volumes of water flowing in the wet season.



A great idea to prepare the site for replanting is to arrange with the community for animals to graze the site first to "cut" the grass and some of the plants, making maintenance much easier.

Do not prepare the land by burning it! You will make it much harder for the new trees to survive and create a lot of maintenance work later. Even clearing all the area without burning is not recommended.

Do not remove all the woody weeds or grasses immediately but use them to protect the young trees from wind and to provide them with some shade. Select the best weeds to produce a lot of biomass in the short term and slowly remove them as long-term trees and plants take over. Keep some weeds in the system as part of long-term land management and animal food production. Use the weeds and grasses you remove for mulch.

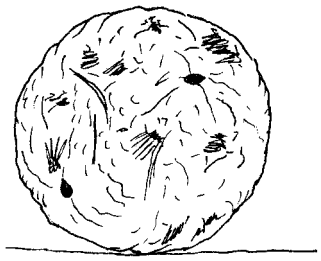


Using woody weeds to protect young trees and provide mulch and nutrients

Removing and burning the woody weeds wastes the nutrients, damages the soil and exposes the trees to wind and animals

Seed balls and direct seeding

A seed ball is round and small – about 4cm in size. It is made from clay and contains tree seeds and a small amount of dry cow or goat manure.

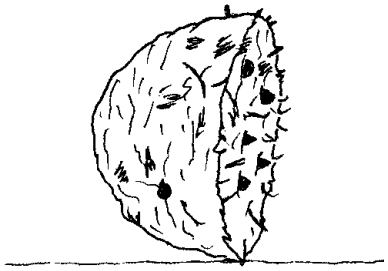


Seed balls are a very good technique to start reforestation in areas that:

- Are very dry
- Have steep slopes
- Have few or no trees

Trees that grow from seed balls grow roots faster than trees from seedlings and, therefore, are stronger and better for surviving tough conditions.

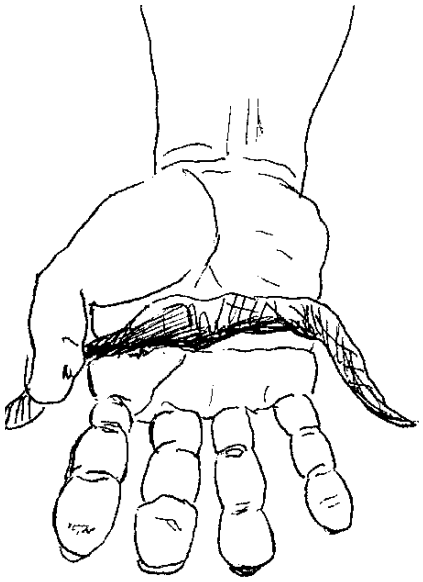
Place the seed balls in the areas you have chosen just before the wet season. When it rains the seeds grow. The clay protects the seeds from animals and birds until the rains come and the manure provides nutrients to help the plants to grow. Use seeds from fast growing native legume trees, and choose species that grow well locally. The trees that grow from the seed balls improve the soil and provide protection and mulch for future trees.



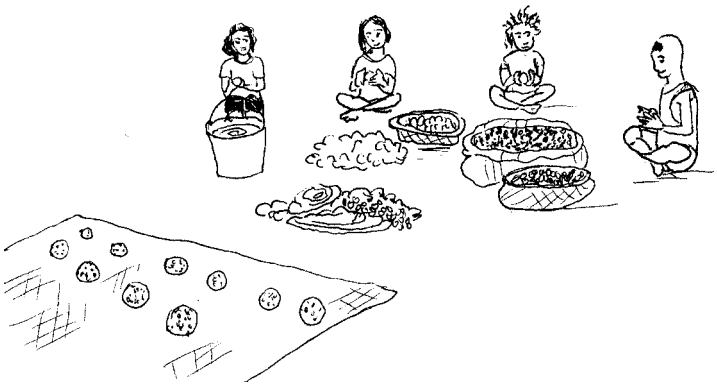
Seed balls can also be made with seeds from other types of native trees. They must be tough varieties and appropriate for the land where you place them.

HOW TO MAKE SEED BALLS

1. Collect the materials.
2. Choose clay that sticks together when it is rolled into a snake shape. Add water to the clay until it is easy to make into balls.



3. Mix in a small amount of dry manure, a little at a time, but make sure that the clay still sticks together.
4. Make the balls and add about five to ten seeds to each ball. The seeds must be well covered by the clay.
5. Put the balls in the sun straight away for one or two hours to dry them. If the seed balls stay wet, the seeds will grow.



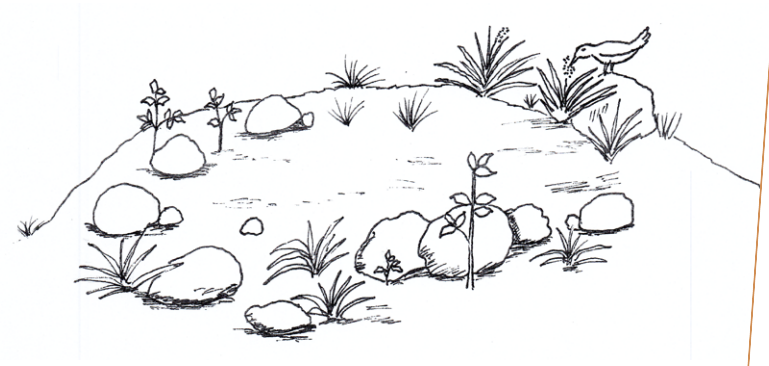
Put the balls in a dry shady place to finish drying. When they are ready store them in a dry place until you use them.

PLACING SEED BALLS

Identify the areas where you want to start reforestation. It is good to place the seed balls close together, a few metres apart at the most. If you do not have enough balls to cover the whole area, it is better to place them in a group and cover part of an area rather than spreading them out. This helps more to survive and makes maintenance easier. The next year you can cover another area.

SOME TECHNIQUES TO IMPROVE SUCCESS RATES ARE:

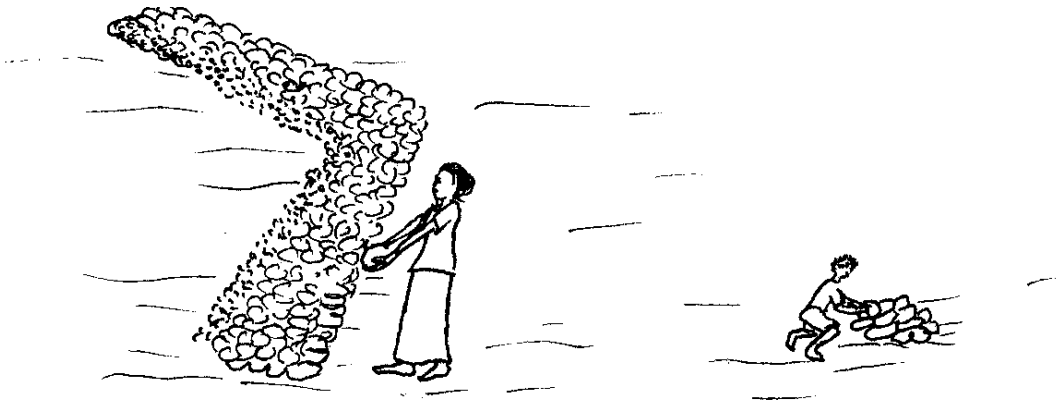
- Make small catchments of rocks which help by catching soil and water for the young trees.



SMART IDEA:

Seed balls help if you have a lot of land that you want to reforest and cannot plant all the land in one season. You can plant trees on the best planting land while using seed balls to start the process of reforestation in the other areas.

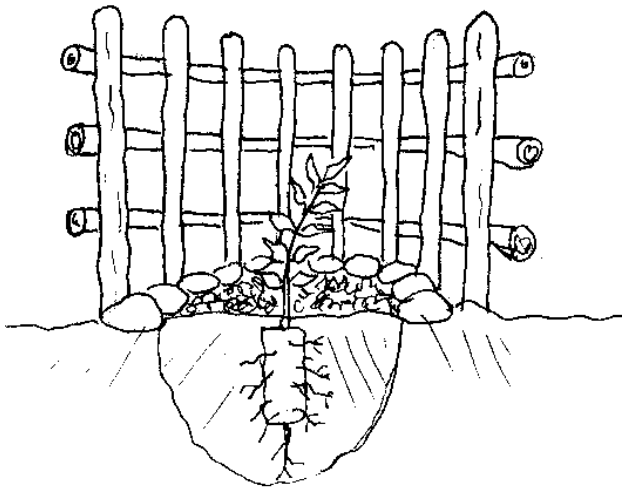
- Use seed balls with small or large swales.



- The information on the best sites to start reforestation later this chapter also advises where to place the seed balls.

Reforestation tree maintenance

PLANTING



Plant trees for reforestation using similar planting techniques to those for fruit trees but with a few small changes. This is because:

- They are usually planted further away from the nursery and resource area.
- They need less fertiliser.
- They are usually not watered so natural water storage is important.
- The ground is often harder to dig.

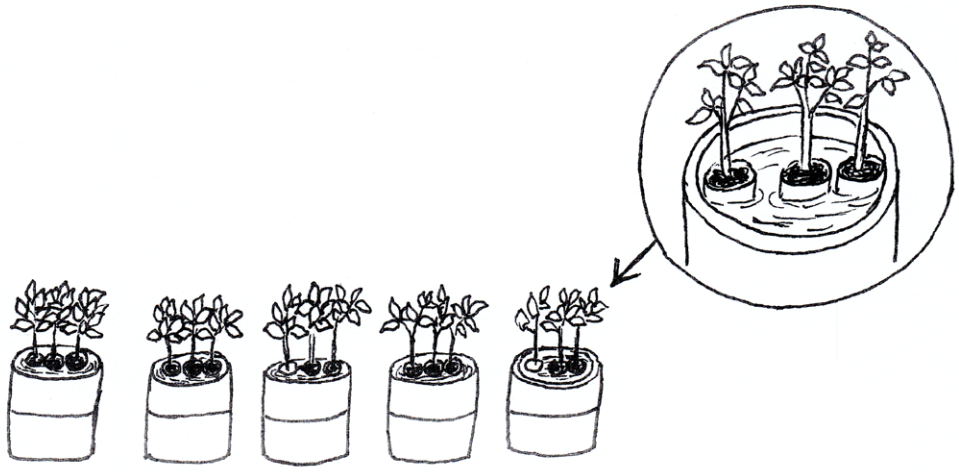
Good planting technique for drier tropical areas

Good planting technique for wetter tropical areas

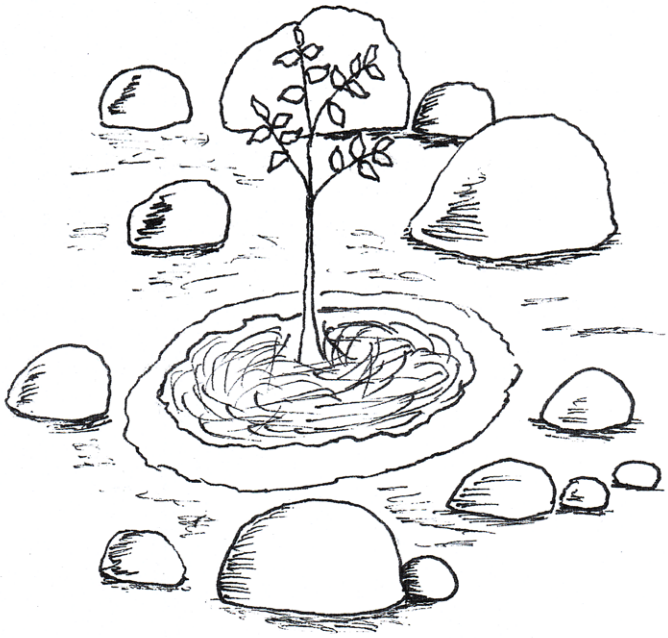
When to plant

Plant trees for reforestation early in the wet season, when consistent rains have started. Follow the same steps as for fruit trees but:

- Soak the tree pots in buckets of water before you take them out to the planting area, and keep them in the shade until you plant them.

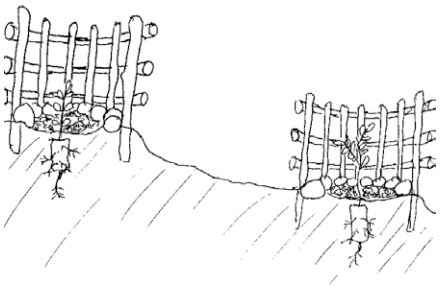


- Dig smaller holes.
- Do not add manure.
- Add some water into the holes, if possible.
- Make a catchment mound next to or around each tree to hold water. Make sure it is above ground level to prevent too much water collecting in the wet season.
- Use bamboo watering pipes to improve results when you water the trees in the dry season.



SMART IDEAS:

- Always place the soil that you dig up BELOW the hole you make. You can then use the extra soil to make the catchment mound to hold water.



- A good way to soak the ground before planting is to dig holes for the trees and wait for the next rain. Water collects in the holes and softens the soil and the trees will grow better.
- Planting with rocks, swales or other water catchments always improves results and helps the trees to grow much faster.
- Make sure you have strong fences or tree guards and community understanding and protection.

WATERING

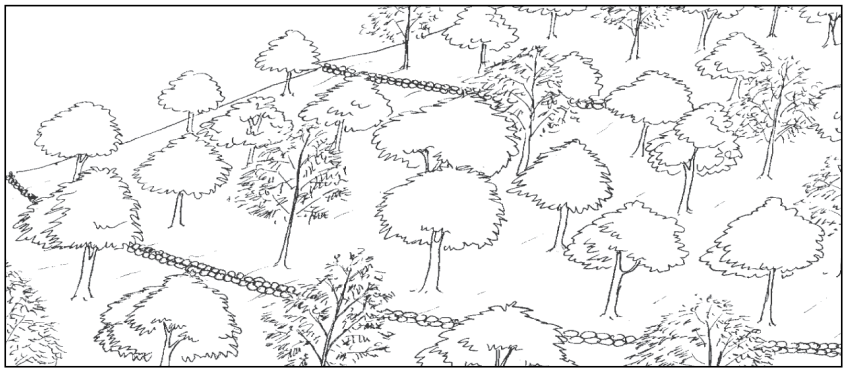
Giving the trees some water in the dry season improves success rates and increases growth.
Always water the trees early in the morning or late afternoon.

FERTILISING

Although reforestation trees need a lot less fertiliser than others, they still need some, especially when they are young. Often where reforestation is planned, the soil has been eroded and burnt. The result is that many nutrients are not available for plants. If you replace these nutrients, the trees will be healthier and grow faster.

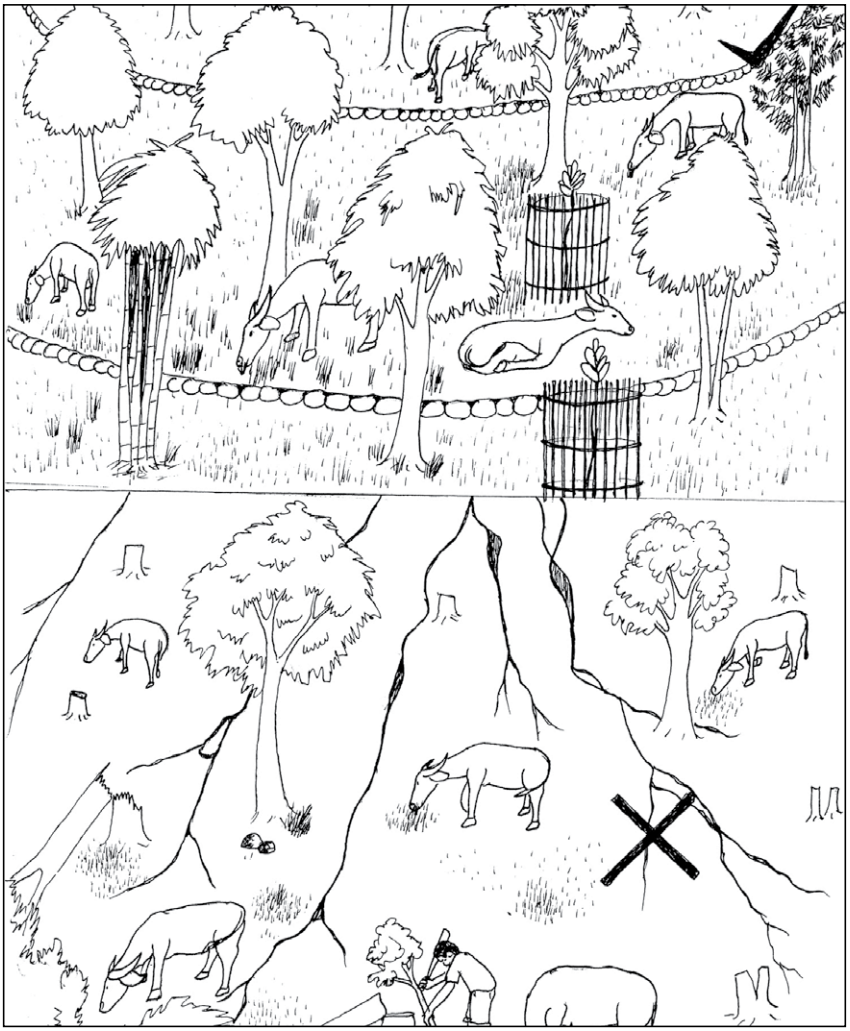
Natural fertilising techniques for reforestation:

- Short and tall sticks are very useful. Near each tree secure a stick in the ground. Small birds are attracted to sit on the short sticks and larger predatory birds on the tall sticks. As they sit they drop manure on the ground, which naturally fertilises the trees!
- Use some compost, manure or seaweed when planting to provide some nutrients for the young trees.
- Legume trees are a very important source of nutrients. Their roots provide nitrogen and they can be pruned up to five times each wet season to make mulch. Use them as "pioneers" and as mulch and nitrogen providers for your other trees.
- Mulch gives many benefits to your trees. For reforestation trees it also provides a lot of the necessary nutrients.
- By using swales, rocks and other methods of catching water, you also naturally catch mulch and fertiliser for the trees.
- After three to five years animals can be carefully reintroduced and managed. The animal manure provides fertiliser for the trees.



1. Legumes and pioneers

2. Planting fruit and timber trees



Introducing animals into the system

MULCHING

Natural mulch, such as tree leaves, grasses and weeds, very quickly builds up when the land is not burned. Collect the mulch and place it around the trees. Prune the legume and other trees each wet season to provide mulch as well.

Mulch stays in place and provides the most benefits if you use swales and other types of water and mulch storage. Rocks also hold down the mulch.

Rocks can act as mulch themselves, especially in dry areas and provide extra water for your trees in the dry season. Read microclimates later in this section for more information.

SMART IDEA:

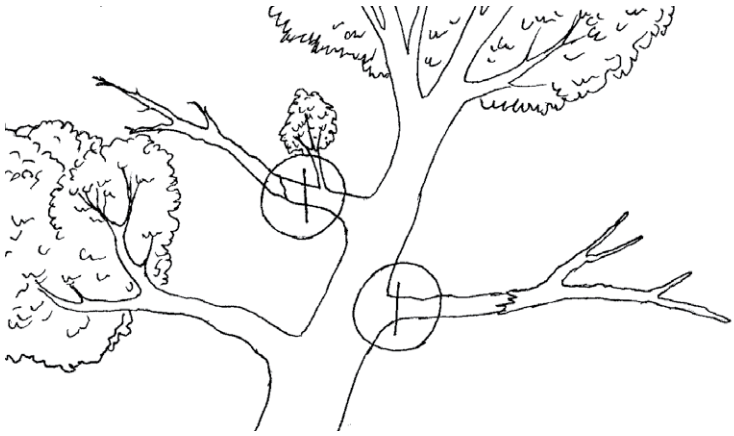
In the dry season mulch burns easily and makes a fire more destructive. Therefore, burning must be stopped on your land and fires prevented from entering your land. Community participation and understanding are important as well as practical techniques, such as making firebreaks. (Read more later in this chapter.)

PRUNING

Reforestation trees need less pruning and maintenance than fruit trees but some pruning can help to improve growth and tree health.

Reasons for pruning reforestation trees include:

- Remove any dead or diseased branches for firewood.
- Removing the lower branches makes access much easier, improves conditions for animal grazing and for growing small plants underneath such as coffee, cacao and vanilla. Do not remove the lower branches of windbreak trees because it reduces their effectiveness.



How to assist natural reforestation

Nature is always working towards a healthy environment with a diversity of trees, plants, animal, birds and insects. For areas where you want to reforest, working with nature speeds up the process.

1. **Stop burning**

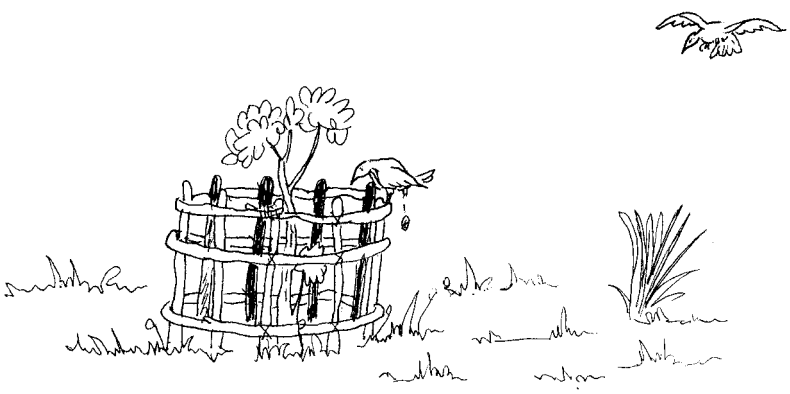
   Burning every year kills young plants and prevents new plants from growing. Only a few types of plants survive: e.g. eucalypts. Grasses give protection to young shrubs and trees, they hold and shade the soil, and provide habitats for small birds, animals and insects. By burning the grasses you remove protection for the young trees, their source of mulch and nutrients and cause other problems too. It makes it much harder for the young trees to grow.

2. **If you want to reforest a large area, plant trees in small groups first.**

   This way the trees provide protection and mulch for each other. The results are better and the trees grow faster. In the following years, plant new trees next to the established trees, which protects and helps the new trees.

3. **Birds are very important for natural reforestation.**

   They also improve areas where trees are planted. Birds eat and spread seeds and fertiliser through their manure, and help to control insects that could damage your trees. The manure helps to improve the soil and some of the seeds will grow into new trees. Birds are an essential part any forest or ecosystem and must be protected and encouraged for an environment to improve quickly. Short and tall sticks are very useful to attract birds, as described previously in 'Natural fertilising techniques for reforestation'.



4. **Creating microclimates.**

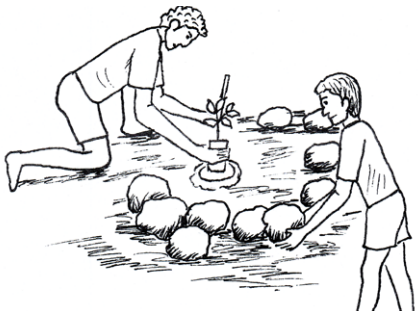
A microclimate is the climate in a particular area. It can be an area of one or two acres, a mountainside or as small as a gully or a swale. Each type of plant has a microclimate in which it grows best. Most plants like microclimates with:

- Protection from strong winds
- Available water
- Good soil
- Sunlight for most of the day
- More shade when the plant is young

Providing a good microclimate is especially important for young plants.

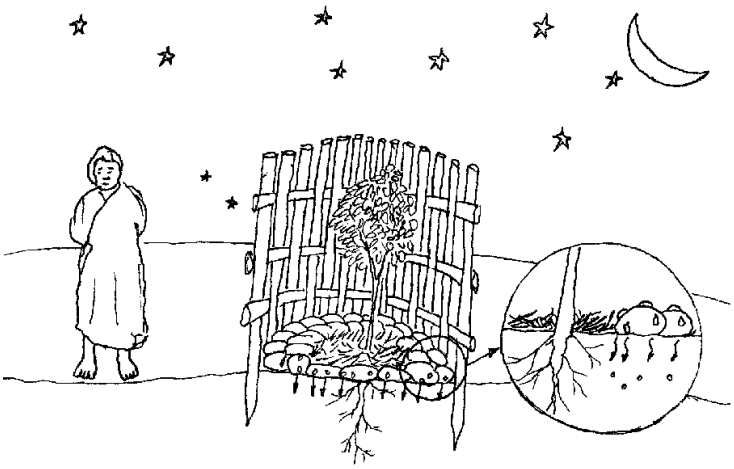
Microclimates on your land can be changed and improved with good techniques such as those that have been explained in this chapter. As a result, plants are healthier and more productive.

Any technique used to catch and store water and reduce erosion improves the microclimate and provides better growing conditions for plants. Even just a few rocks and sticks on the ground change the microclimate slightly and improve conditions for trees to grow!



A construction made from rocks – rock swales, rock terraces, net and pan systems, boomerang swales, etc. – helps to improve the microclimate and environment a lot. The rocks also provide homes for small animals and insects.

At night, when the temperature drops, the rocks cool down and moisture from the air collects on them. This moisture then drips off the rocks into the soil to be used by the plants. It is an important source of water in dry areas, especially in higher altitudes.



Protection from animals, fire, wind and erosion

All fruit trees, tree crops and reforestation areas must be protected from fire, animals, strong winds and erosion.

Fire and animals quickly destroy many trees and waste a lot of hard work. Strong winds damage young trees, slow down growth and the trees need a lot more water. If the trees are protected, they grow and produce well. Erosion removes young trees and the soil that they need to grow.

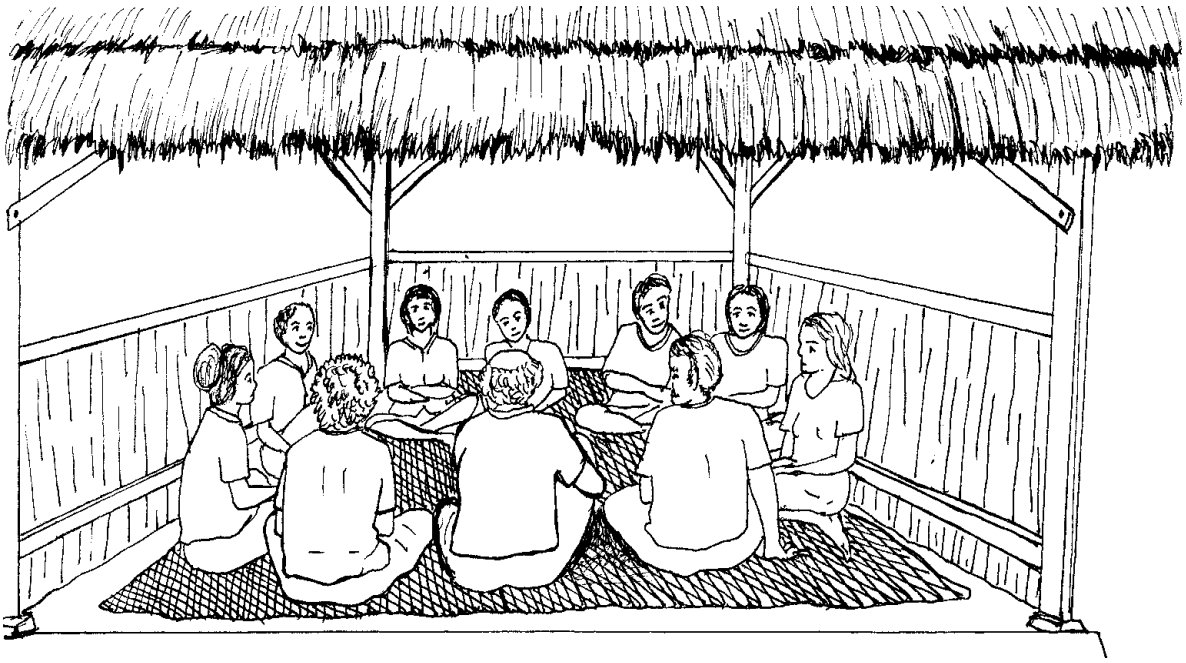
The first step and most important part of tree protection is community participation.

Community participation

Neighbours and communities need to be involved in and understand any project that affects them or their area. Community meetings are important for discussing issues such as:

- Preventing animals from going into areas where young trees are growing
- The benefits of not burning and preventing fire from spreading from one family's land to another
- Sharing water, and sharing the labour and construction costs of collecting and storing water
- Organising community work gatherings. These maximise community involvement, get a lot of work done in a short time, and you can share a meal afterwards to celebrate!

If the whole community understands the benefits of not burning and of animal control, reforestation is much more successful.



Develop appropriate community plans to manage the land and help prevent problems from occurring.

- Hold ceremonies and apply traditional community law to show the importance of reforestation and protect the trees: e.g. *Tara Bandu* in Timor-Leste. See 'Traditional law' below.
- Community education about reforestation and stopping burning and erosion benefits EVERYONE in the community and improves the results of reforestation projects. Schools, local groups, churches, government agricultural workers and community radio are all groups that can be involved.
- Organise user groups for water and other resources to manage them and provide fair distribution to benefit all users.
- Arrange a system of exchanges for labour and resources.
- Develop short- and long-term plans for erosion control, tree growing, tree planting and transporting and selling products.

Community education on reforestation and community nursery

Ideas and plans for community land management should be discussed with government agricultural workers and other government departments. Working together with the government is important to improve results and increase community involvement.

Community ownership

Community ownership and development is very important, especially for community land.

There are many benefits from community projects and from more than one landowner participating in a project, such as creating a community nursery, constructing swales and other water catchments, water supply, animal housing and fencing. Some of the benefits:

- Sharing the costs of materials and labour for projects
- Swales and other water catchments work better if different landowners are involved. This is especially true for those who share a water catchment.
- Produce opportunities for trading
- Sharing the transport of produce to markets and the sale of produce
- Protection of trees from fire and animals is more successful when people work together.
- An important part of community education and working together is to understand the **future** benefits.

Community group planting and protecting trees on community land

If reforestation is well managed, in three to five years animals can be reintroduced into the area without damaging the trees. The animals will be healthier from more shade and good quality food, and provide weed control and manure for the trees. As a result, the land will be much more productive.

Now we look at practical techniques for tree protection. Remember to find multifunctional solutions.

SMART IDEA:

It is very important to make long-term plans for large areas of land, especially to prevent erosion problems. It is even more important to do the work step by step: make each small step a success rather than try to reforest a large area and not be able to manage it properly.

Traditional law for natural forest management

Traditional laws are common in tropical cultures, including for forest and land protection. This can include land that has existing forest, land that is being reforested and community agroforestry projects. The land is protected from:

- Burning
- Harvesting
- Hunting
- Animal grazing

An example of this is *Tara Bandu* (a ceremony which hangs an item in an area to show it is off-limits) from Timor-Leste. During the ritual ceremony a group of elders announces the rules that are to be followed by the community members gathered. They also choose a group of elders within the community, called 'Kableha', to be responsible for administering the rules, and they make sure community members do not break the law until the *Tara Bandu* period finishes. These tasks can include looking after forests and native animals, rivers, lakes and food sources within community. Sometimes, *Tara Bandu* permits some harvesting, hunting or grazing but only by a few people and under tight control.

The punishment for breaking the law is to pay for another ceremony and admit the mistake to the community. It is hard to break the law and avoid confessing without other community members knowing. As the *Tara Bandu* ceremony is sacred, people believe that those who break the law will be cursed by nature; they may get sick, have an accident or even die.

Tara Bandu is entirely community run; however, it can be initiated by government with the community to improve supervision and results for government agroforestry, reforestation and land management projects.

Protection from fire

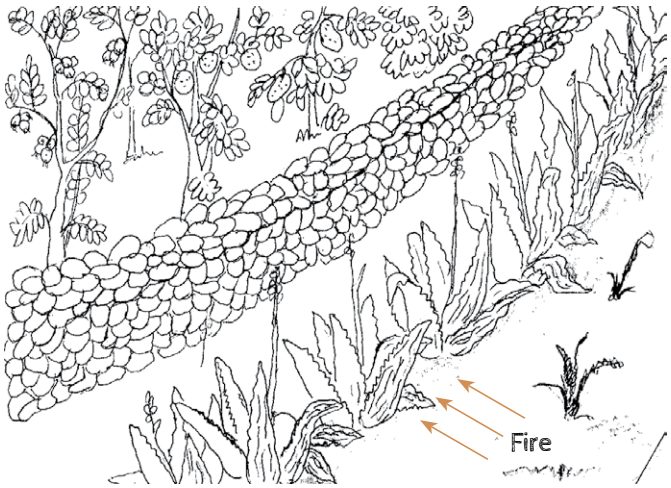
Question: Where is a fire most likely to come from?

Answer: From where the wind usually blows in the dry season or from lower down the mountain. Put your fire protection in this area first.

Fire protection can be:

- Living fences made from trees or plants that do not burn
- Rock walls. A rock wall is good because it provides fire and animal protection.
- Firebreaks. A firebreak is a bare strip of land that is kept clear of plants and leaves. (Use the leaves as mulch for your fruit trees!) When a fire reaches a firebreak it slows down or stops because there is nothing to burn. A well-managed bamboo row makes an excellent firebreak. Read the Bamboo chapte**r (Ch 16)** for details.

These techniques work much better if they are combined together.

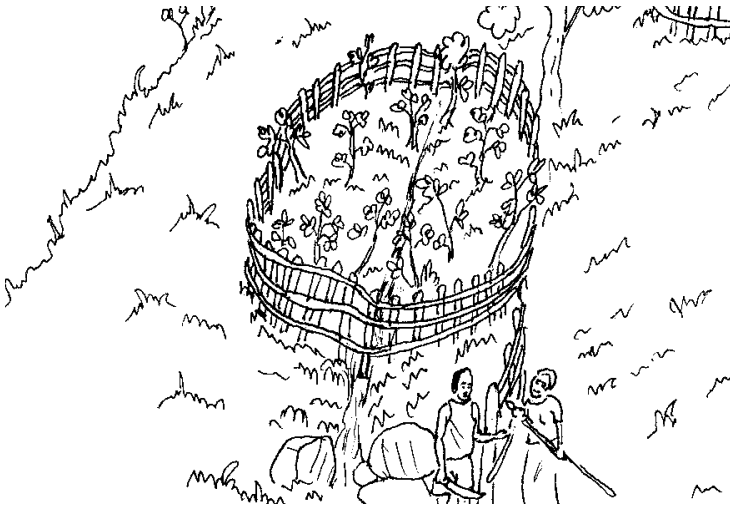


Protection from animals

A fence or tree guards must be used if there is any chance of animals eating the trees. Goats, buffalo, cows and pigs can destroy large numbers of trees very quickly. Fences are good for fruit tree crops, reforestation areas and groups of trees.

They can be:

- Living fences made from trees that animals do not eat: e.g. cactus, flame tree, bamboo. (Test the types first as some are eaten and some not. Use bamboo that has hairy shoots and big thorns.)
- Wood, palm branches or cut bamboo
- Rock
- Wire
- A combination of materials



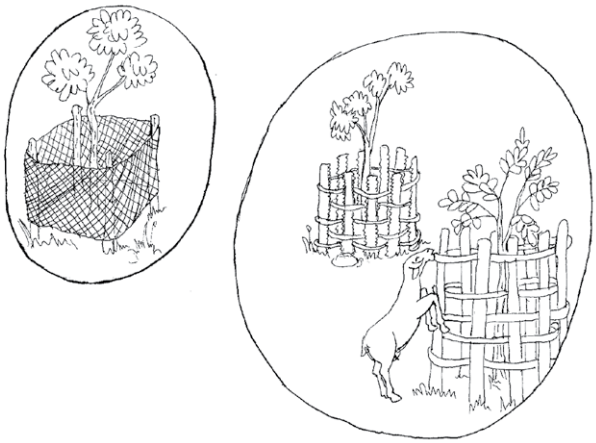
Tree guards are good for fruit trees, trees near the house and trees that grow large.

They can be made from:

- Palm branches – spiky palm branches are best
- Bamboo
- Wire
- Wood
- Rocks
- Old fishing nets
- Anything that successfully stops animals

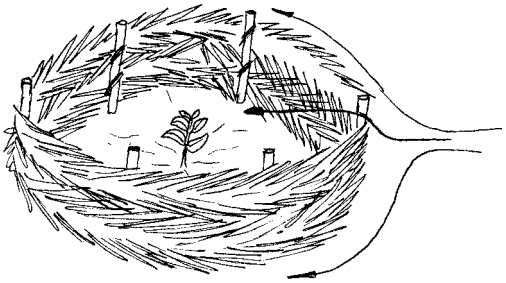
Tree guards and fences must be strong enough to stop hungry animals!

Rocks also provide moisture on cold nights and fire protection. Tree guards can be re-used or turned into mulch. Remember that when trees have grown up animals can be carefully reintroduced into the system.



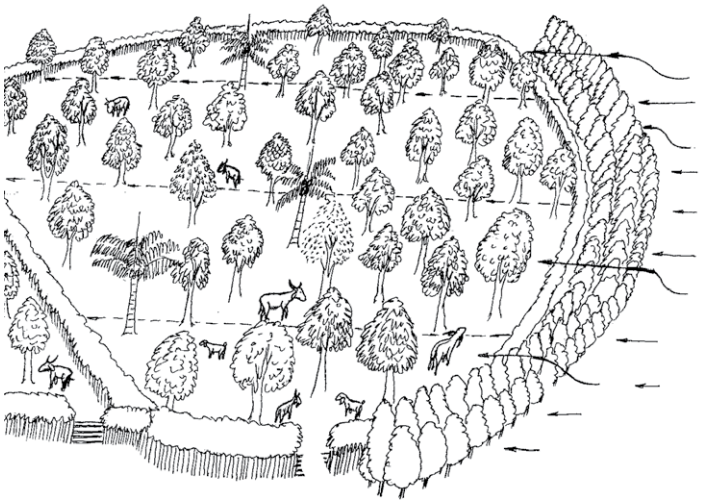
Protection from wind

If trees have protection from wind, they grow faster and are healthier – especially when they are small – and their water use is reduced. Tree guards provide some wind protection for young trees. Fences also provide some wind protection for young trees, especially if vines grow over the fences or they are living fences.



FOR TREE CROPS AND FRUIT TREES

Plant windbreaks in the areas where strong winds come from. A windbreak is a line or lines of trees planted specifically to reduce wind. Windbreaks can be grown from many different useful trees. Look in the Permaculture design strategies and techniques chapter (**Ch 3**) for more windbreak examples.



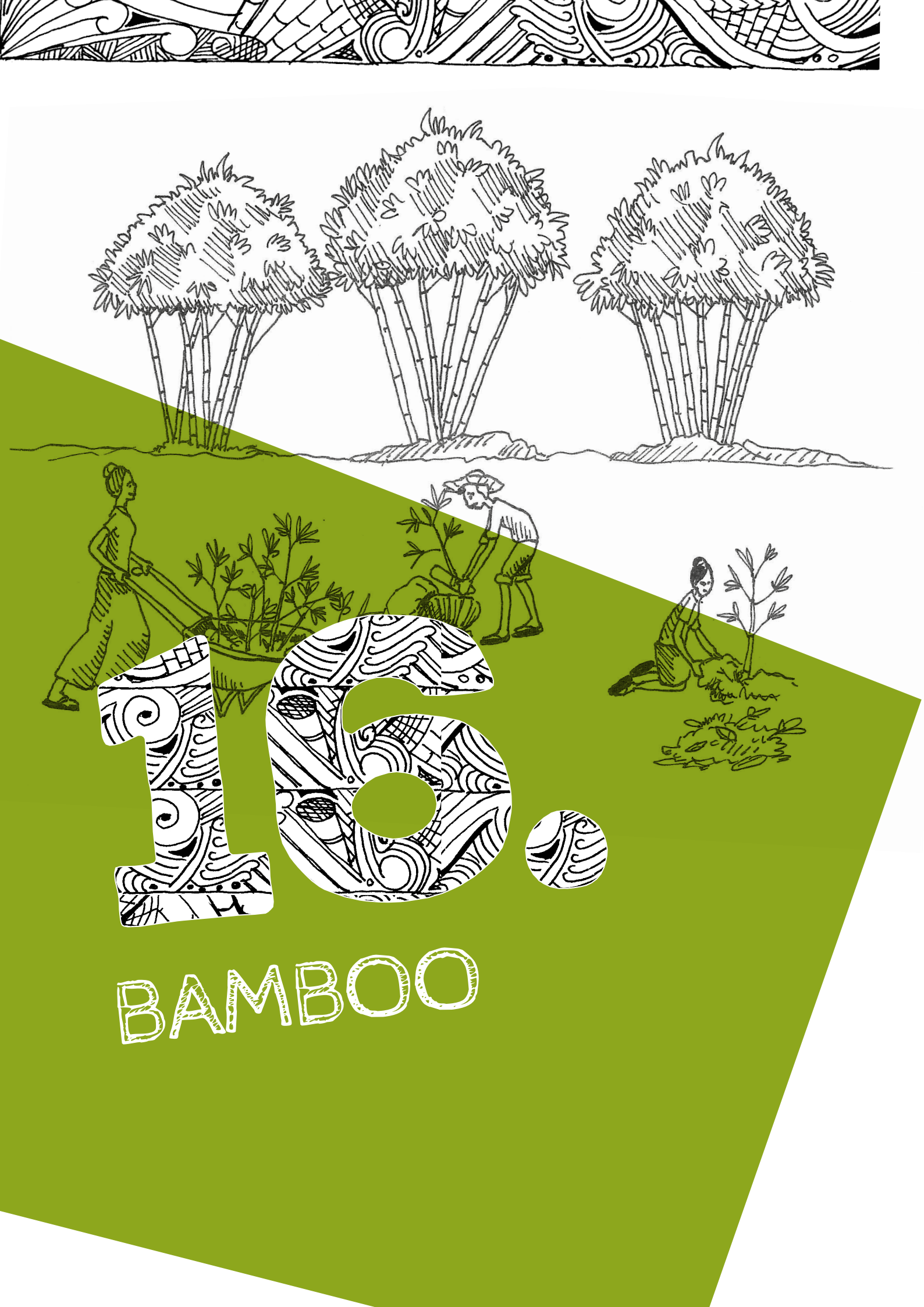
FOR REFORESTATION

- Plant trees first in areas that are protected from strong winds.
- Plant trees in groups. As they grow the trees protect each other. The next year use these groups of trees to protect new trees.

Protection from erosion

Trees are the best long-term solution for erosion but when trees are small they need protection. Many solutions have been explained already in this chapter, including swales, terraces, boomerang swales and more. Grasses and ground cover are very important for stopping erosion. Burning damages and kills grasses, ground covers and young trees and must be stopped if erosion is to be stopped.

TREES
CHAPTER NOTES



16.

BAMBOO

16. BAMBOO

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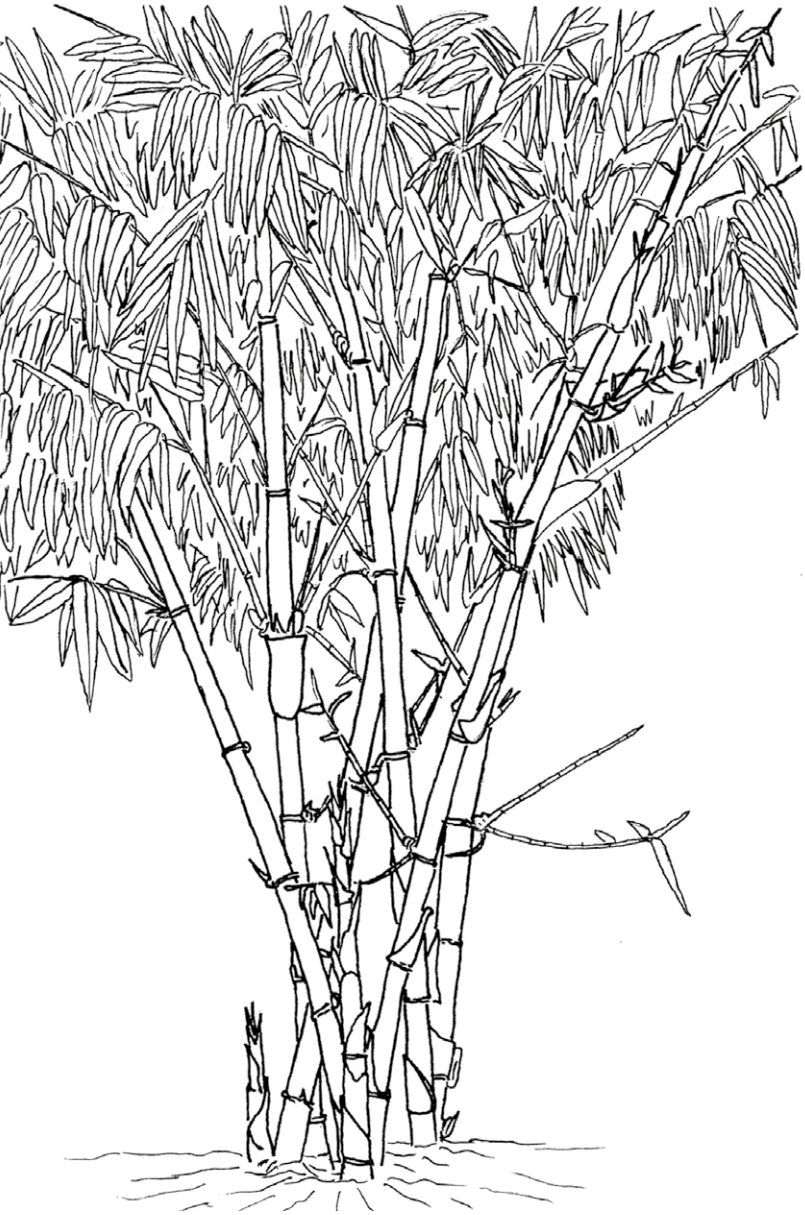
Bamboo

Bamboo grows all over the tropics.

It is a plant that provides many different products, fulfils many functions and generates income in many different ways. It also grows very quickly, and reaches maturity and usefulness much quicker than most trees. One of the most important functions of bamboo is that it can replace much of the need for wood, and can be harvested every year instead of only once.



Bamboo can be used for:

- Building houses and shelters
- Furniture
- Food for people and animals
- Bamboo wood or charcoal for cooking
- Musical instruments
- Containers for cooking, storage and plants

Bamboo can function on a garden or farm as:

- Windbreaks
- Erosion control
- Shade
- Fencing and living fences
- Irrigation pipes
- Trellising
- Charcoal biochar for soil improvement (see Soil **Ch 9**)
- Mulch–bamboo leaves
- A Compost and liquid compost ingredient–bamboo leaves

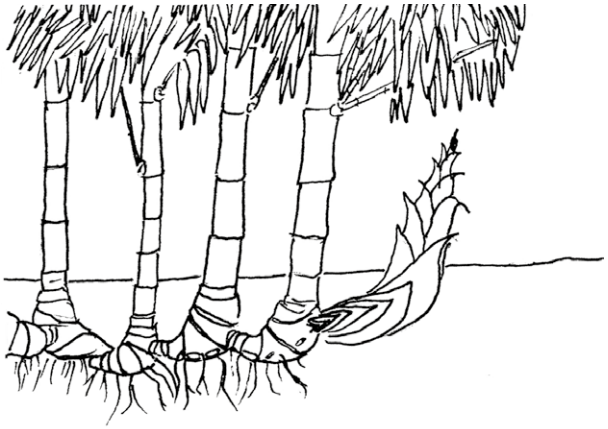
The process of correctly growing and managing bamboo clumps is the first step to producing high quality culms (poles) and shoots that are easy to harvest.

Bamboo varieties

Bamboo is divided into clumping and running varieties.

CLUMPING (SYMPODIAL OR PACHYMORPH)

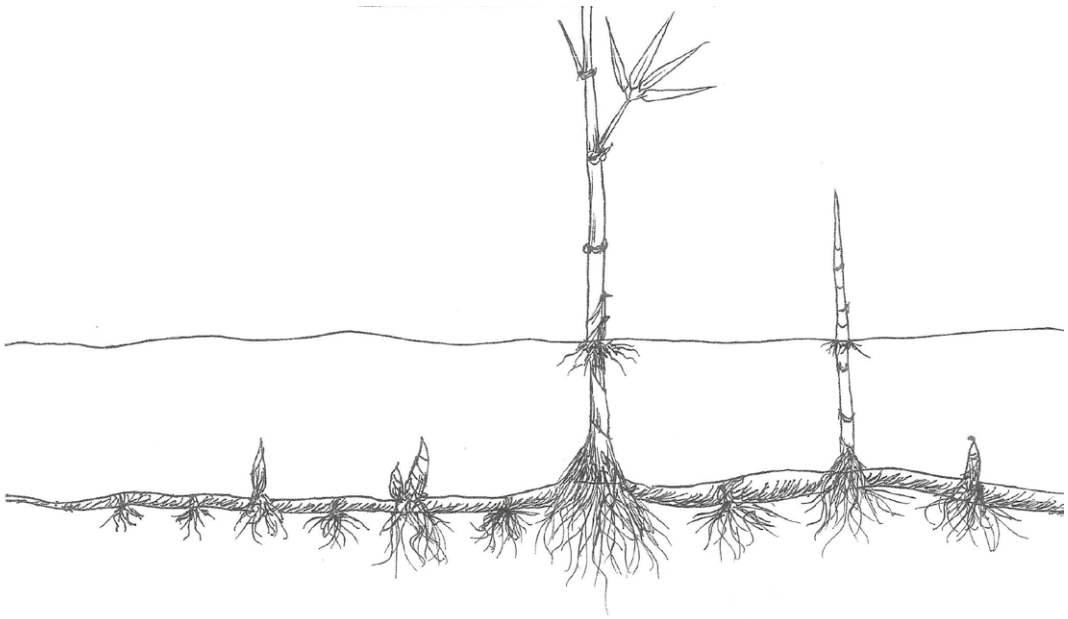
These are bamboos that slowly grow out from the base in a circle to a maximum diameter, which varies according to each species. Each new culm (pole) grows from a bud at the base of an older culm. Clumping bamboos are easier to control than running bamboos, and are most commonly found in the tropics.



Culms (poles), New shoot, Rhizome, Roots

RUNNING (LEPTOMORPH)

As the name suggests, these bamboos keep spreading. They have a different root and growth structure to clumping bamboos, sending out long roots with many culm buds. New culms can grow from underground as far as ten metres from the original plant. They originated in temperate areas but grow very well in the tropics. Running bamboos can be very useful, including for erosion control and earthquake security, but they are also very invasive. Running bamboos are not recommended unless they can be absolutely controlled, which is very difficult, or are native to an area. However, even when they are native, they are invasive and hard to control.

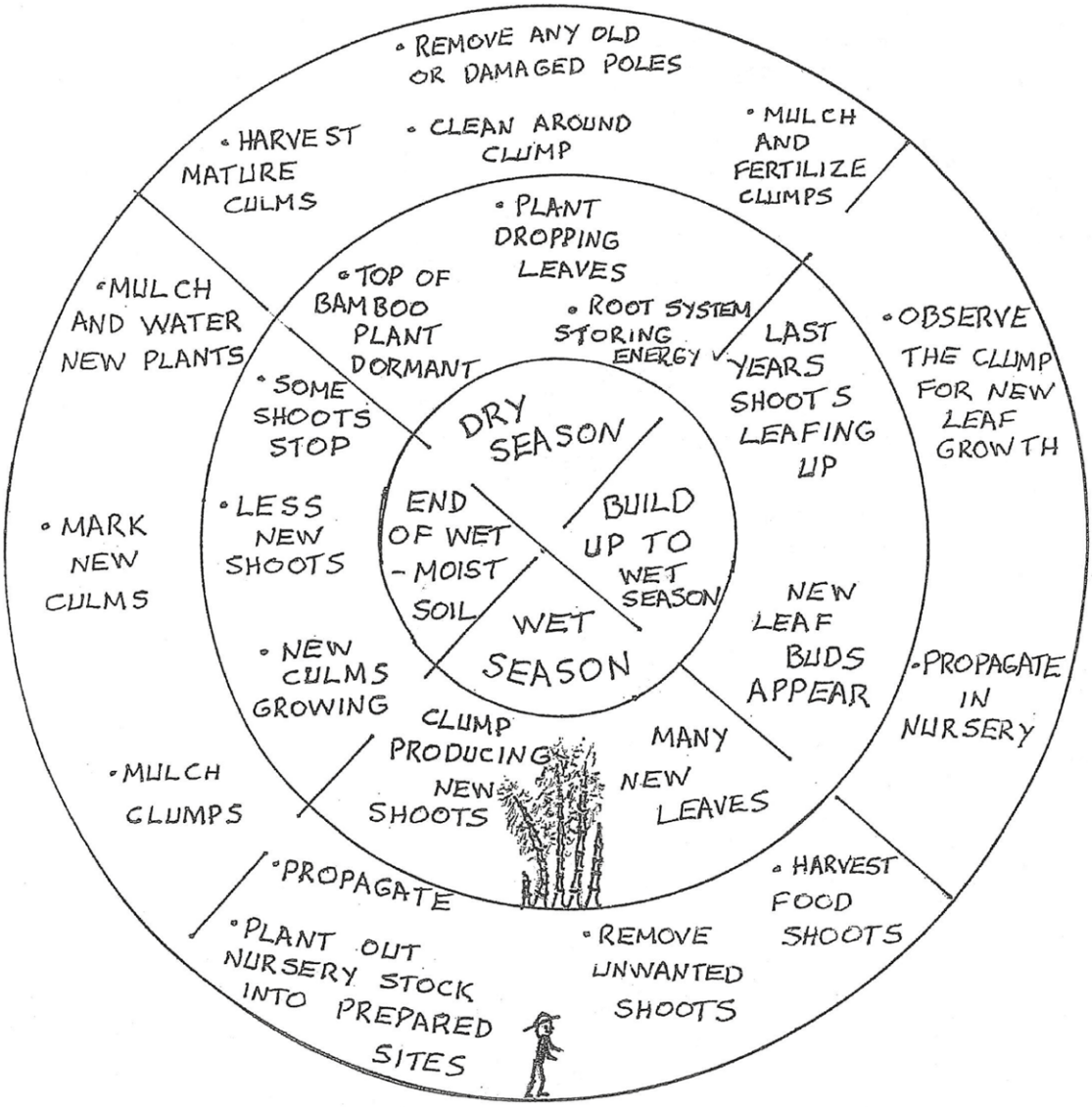


In this chapter we focus on clumping bamboos: there are hundreds of different types that provide all of the different products and functions that make bamboo so useful.

The yearly bamboo cycle

Like any plant, bamboo has an annual cycle. This includes the growth and aspects of the bamboo plant during the different seasons, and the best time for various propagating, maintenance and harvesting activities. When we work with the cycle, it is less effort. Quality and productivity increase as well.

In the diagram below, the inner circle is the seasons, the middle circle is what the plant is doing and the outer circle is what we are doing.



Bamboo propagation

There are two main techniques for propagating bamboo. These are Rhizome propagation and Culm Cutting propagation. The method you use depends on the type of bamboo, and what you want to use the bamboo for.

Time to propagate

Just before and during the wet season are the best times of year to propagate bamboo, but with careful management, and if water is available, it can be done at any time. If no water is available, propagate when the wet season has started.

Rhizome propagation

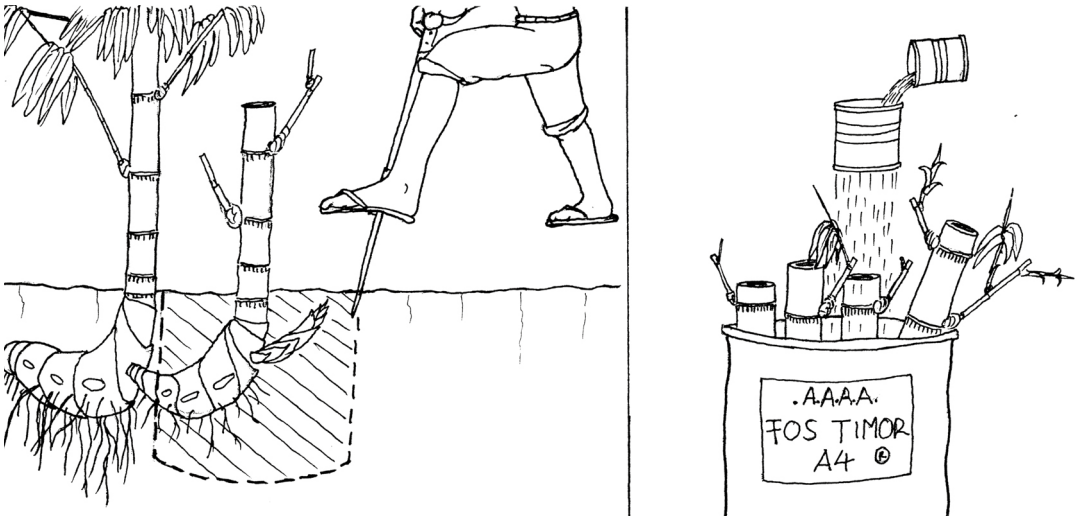
Rhizome propagation is good for small-scale planting because it has a higher success rate than culm cutting, but it is more work.

TYPE OF BAMBOO

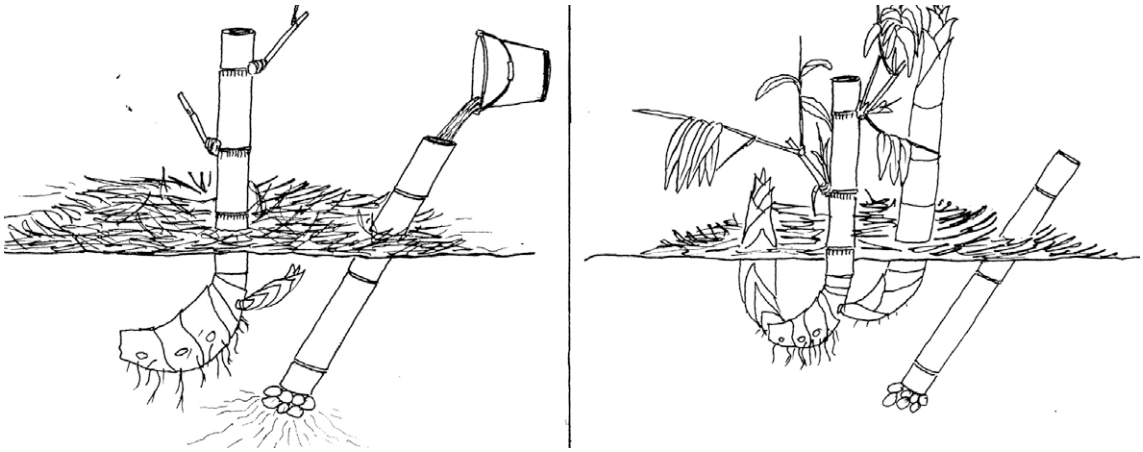
Rhizome propagation works with almost all types of bamboo, but rhizomes of large species are difficult to dig up. Therefore, rhizome propagation is best for species of small bamboo with many rhizomes and culms.

Method

1. Select the rhizome and culms you want to propagate. One and a half to two year old culms on the outside of the clump are easiest and best.
2. Cut the culm three or four nodes above ground level.
3. Cut through the rhizome where it joins the next rhizome (mother rhizome). Usually this is towards the centre of the clump. Dig up the roots and soil 10 to 15cm away from the culm, so that when you remove the rhizome the roots and soil are attached.



4. Replant the rhizome immediately. If this is not possible, keep the rhizome roots wet at all times until you are ready to plant. Wet the leaves as well. Keep the rhizome and roots away from sunlight.
5. Plant the rhizome 15cm into the ground and give it LOTS of water. Fertilise the new bamboo with compost and manures, and put a thick layer of mulch around it. Water regularly. New leaves and branches will grow from the nodes, and at the beginning of the wet season, new shoots will grow from the rhizome. Sometimes new shoots grow straight away.

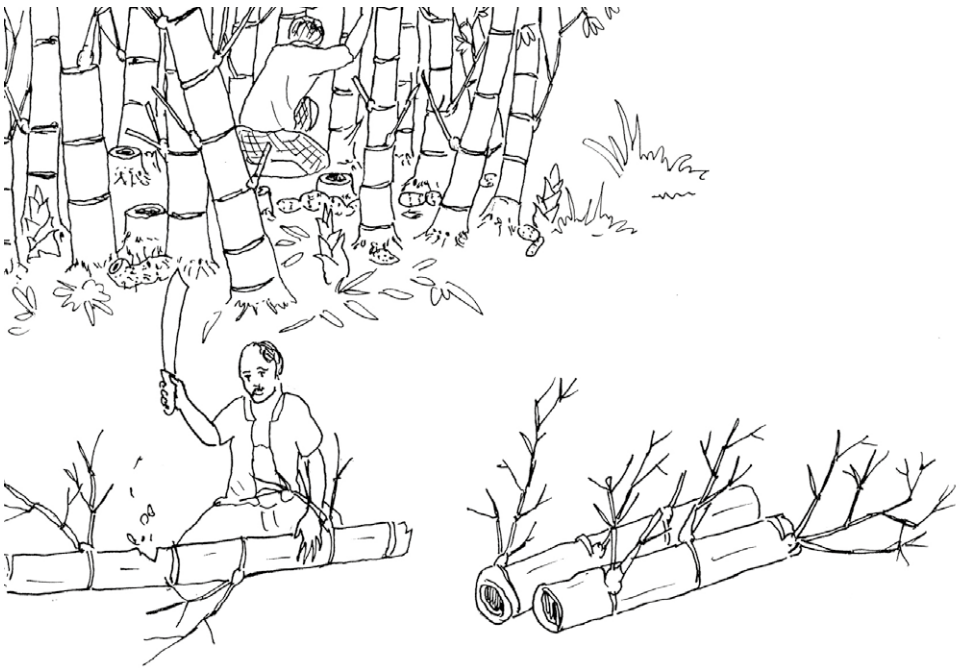


Culm cutting propagation

Culm cutting propagation is good for plantations and windbreaks because it is a simpler process. The best time to propagate is at the beginning of the wet season.

TYPE OF BAMBOO

This technique is best with large bamboos that are too hard to propagate from rhizomes, but you will have some success with most types of bamboo.

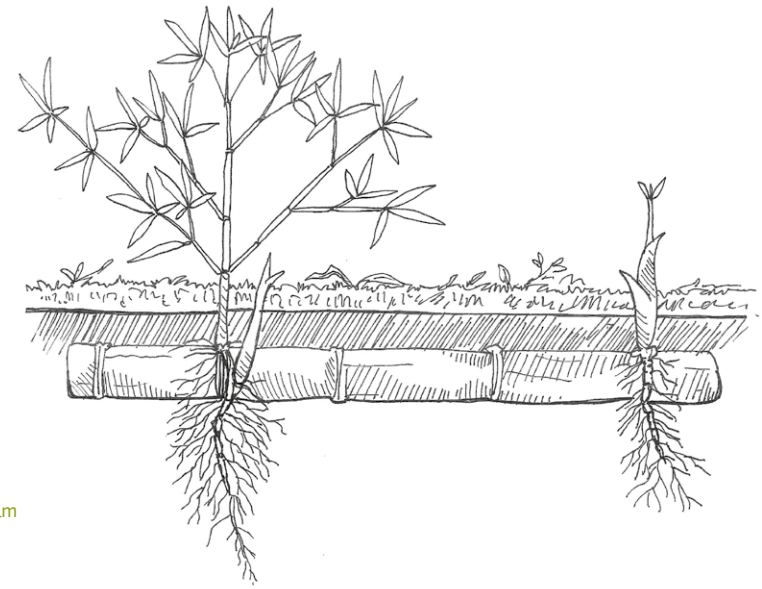


Preparing the culms for planting

Planting the prepared culms

Method

1. Choose a culm that is one and a half to two years old and has well developed branches.
2. Cut it as close to the ground as possible. Discard the very bottom and the top third and then cut the culm into one to two metre lengths.
3. Look carefully at the branches and choose the side with the best developed branches. Cut these back to about one metre and, on the other side, cut the branches off.
4. Dig trenches for the bamboo culms. Bury them horizontally 15cm below the ground, with the branches pointing up out of the ground. You can make a 'V' shaped cut in the bamboo culm between the branches, and fill the culms with water mixed with a small amount of dried manure. This ensures that the plants stay moist while they grow new roots. Mulch them well: they need to stay constantly wet until they grow roots. Depending on the species, new root growth can take between six weeks to six months. Even if the cuttings look completely dead, do not dig them up until the next wet season: they may just be dormant and will grow once the rains come.
5. Water the bamboo well every day for the first week. After that, water it twice a week for a month.



New growth on a planted culm

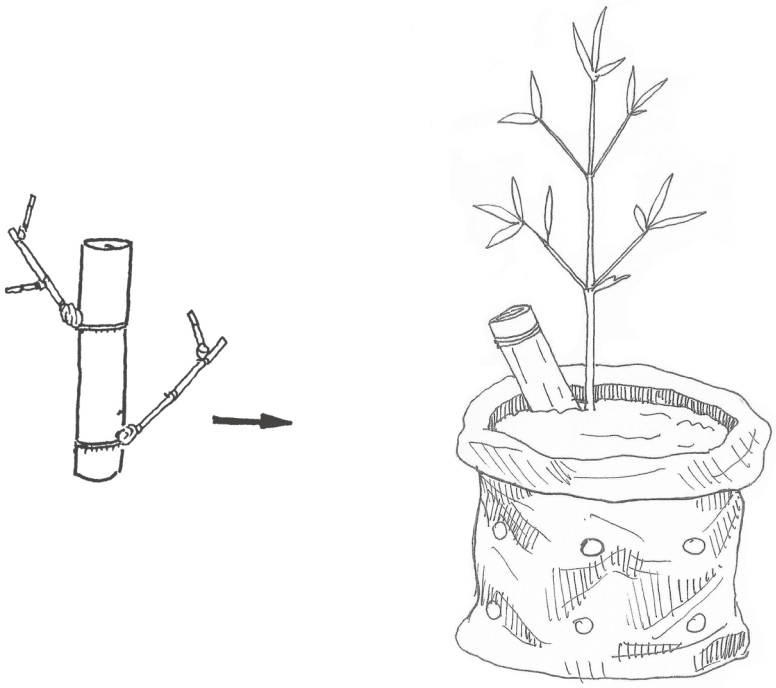
PLANTING THE CULMS

Plant and propagate the culms in the place where you want to grow them. Or the culms can be planted close together in one area so they are easier to manage. Then you can dig them up, cut up and replant them once they are growing, at the beginning of wet season.

1. Digging up new growing culms
2. Dividing the culms into separate plants
3. Planting out new bamboo plants

NURSERY PROPAGATION

Culm cutting propagation can be used for growing bamboos in large containers as well. Select a culm one and a half to two years old with well developed branches. Only use the middle third of the culm for propagation. Cut the culm into sections, with two nodes in each section, 5cm below each node. Only use the sections that have well developed branches. Trim the branches back to the second node on each branch. Plant the section on an angle with the branch standing vertically. Make sure the node is at least 5cm below the top of the soil. Water the bamboo so that the soil stays moist.



Where to grow bamboo for the best results

Different types of bamboo are grown for different needs. Some are grown for culms, some for edible shoots, while others are for land and environmental management.

Quality culms

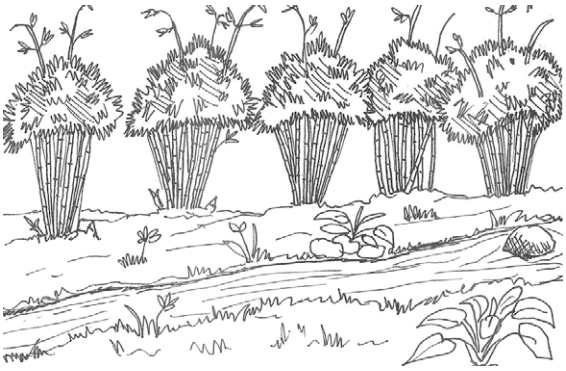
Tests on bamboo show that the culms are higher quality when they grow on hillsides rather than near rivers or flood plains.

This is because clumps on hillsides grow slower and have lower water content, so the culms are stronger and more borer resistant.

Edible shoots

Bamboo for edible shoots is better grown near water on flood plains or where irrigation water is regular.

The extra water leads to faster growth, more shoots and a better taste. Shoots that grow too slowly are tough and bitter.

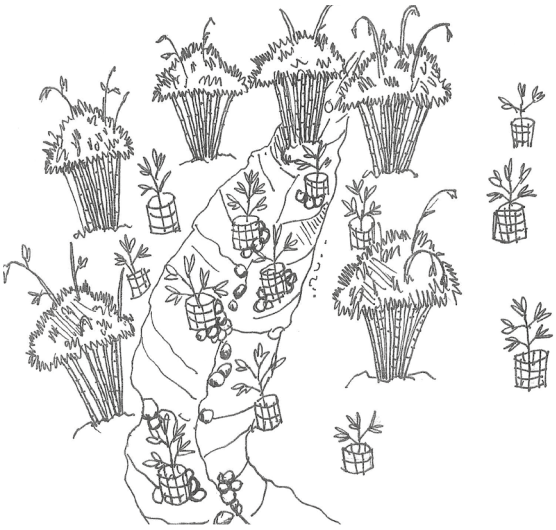


Land and environmental management

There are types of bamboo with culms and shoots which are good as windbreaks and fences, especially types with large thorns.

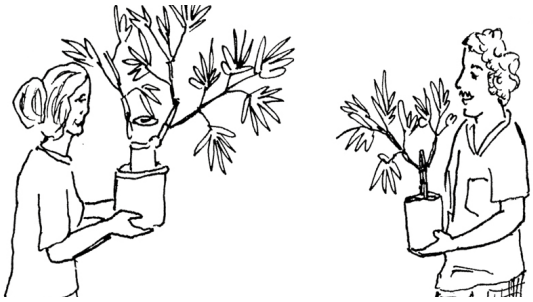
What you choose depends on your needs, the land conditions and how much irrigation is available.

For erosion control and reforestation the culms or shoots are not the first priority. Choose types to suit your needs and the land. There will still be some harvesting possible, but these areas should not be planted with bamboo grown for income. One of the best species to grow for erosion control is an open-clump bamboo, Bambusa vulgaris (common bamboo). This bamboo is the most common throughout the tropics and grows really fast.



How to grow high quality bamboo culms

There are hundreds of different species of bamboo growing in the tropics. All of them have different uses, and some are better quality than others. If you want to plant bamboo, first decide what you want to do with it, and then ask around your community and bamboo experts for the best variety for your purposes.



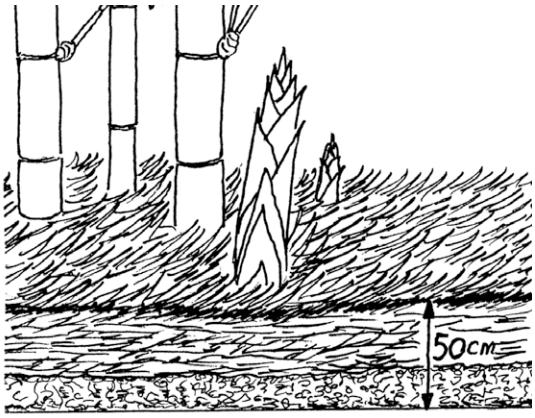
By sharing and planting different species of bamboo in different areas, everyone can have access to a large range of good quality bamboo.

Fertilising and mulch

To grow high quality bamboo it is important to feed the plants when you first plant them.

Compost or manures are best. Bamboo plants are heavy feeders: this means they **love** food. They also have root systems that grow close to the surface. Therefore, it is best to feed bamboo small amounts regularly (every three to four months) rather than large amounts once a year. Make sure they are fertilised just before the wet season. Be very careful if you use urea: it is very strong. As bamboo roots are close to the surface, large amounts of urea can kill them.

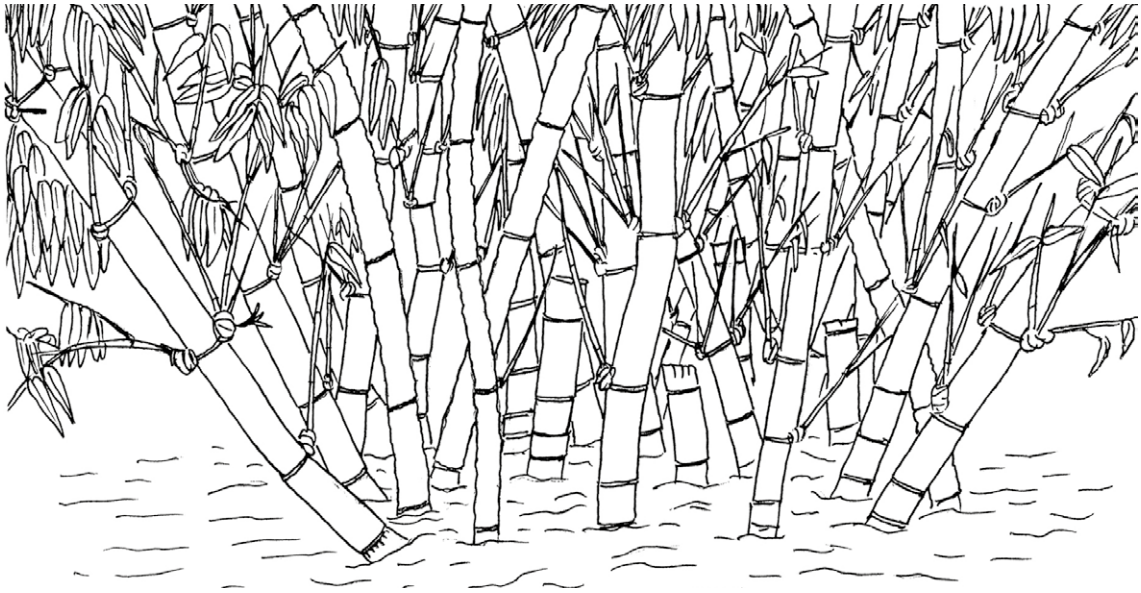
It is also very important to mulch the plants. Bamboo grows best with at least 20cm of mulch. When the plants are two years old you can put a thin sprinkle (one small shovel full) of cement powder around the clump (put this under the mulch). Cement contains silica, the mineral that makes bamboo hard, and it helps to improve culm quality.



Clump management

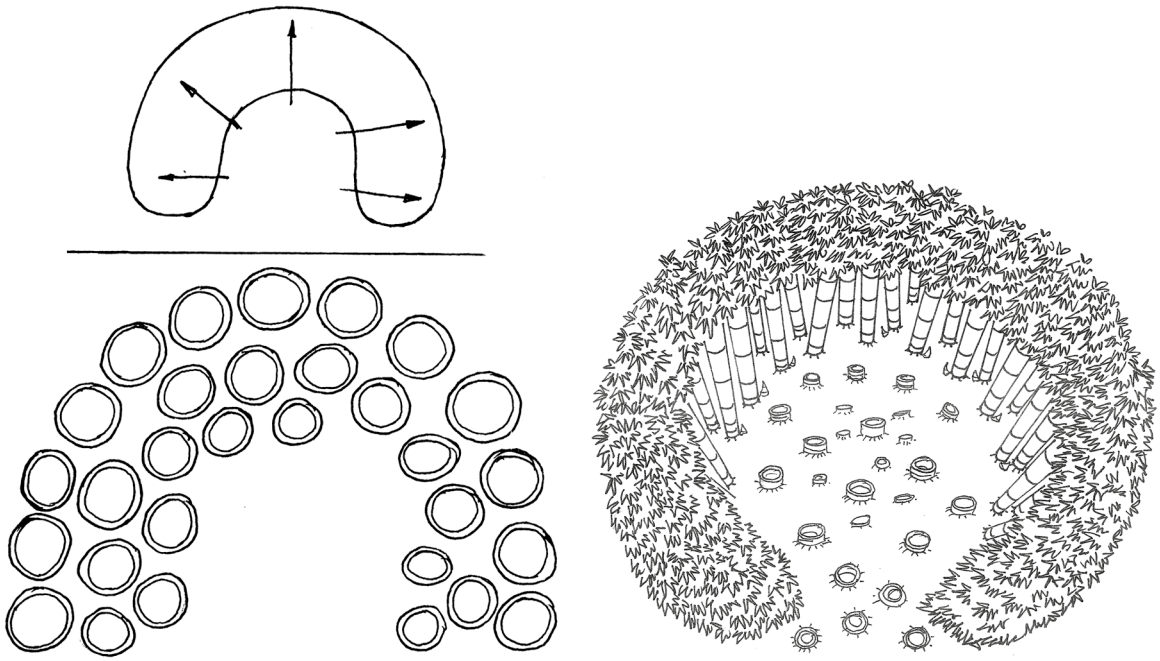
A properly managed clump of bamboo produces high quality timber, and harvesting is quicker and easier.

A managed clump is open and healthy and has a range of culms, from shoots through to those ready to harvest. An unmanaged clump is tightly packed, often with dead or dying culms in the middle. It is very difficult to harvest.



Unmanaged clump

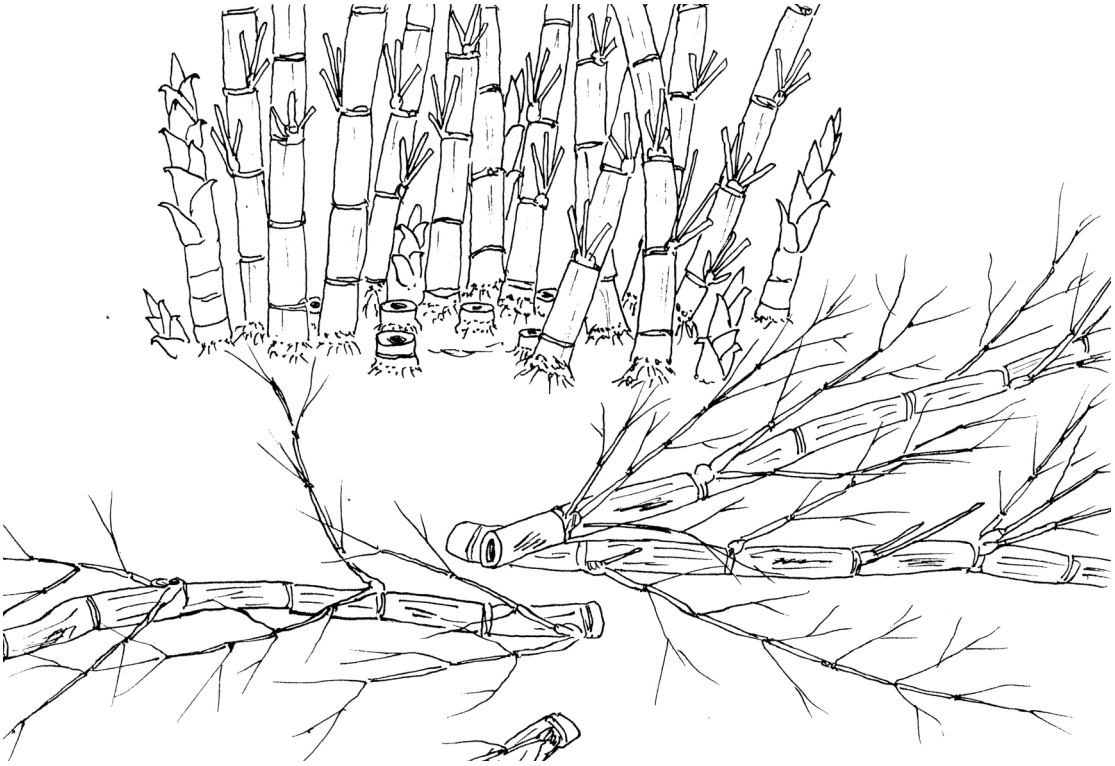
The first step in managing a clump is to remove all dead or old culms. This is often difficult because these will be in the middle of the clump. One way is to cut into one side of the clump to the middle, and cut out the old culms. Cut them as close to the ground as possible. This creates a shape that allows you to harvest the mature culms from the centre of the clump without damaging the new shoots that are usually on the outside.



Well managed clump

THINNING

Once you remove the old culms, the next step is to thin the clump. Take out any culms that are damaged, bent or too close to other culms. If someone has harvested the clump before, it will have a lot of culm stumps. Cut them to just above ground level to make access easier.



BRANCH PRUNING

Remove the lower branches to improve management and access to the clump. It is important to cut them at the second or third node on the branch, so that fungus cannot enter the culm.

Once the clump is thinned, tidied and the branches pruned, it should have three, two and one year old culms and new shoots. (Read in 'The age of bamboo' section later in this chapter for how measure the culm age.) It is best to have six or eight of each, making a total of 24 to 32 culms. When the clump is eight or more years old, you can increase–up to twelve–the number of shoots that grow. This is because the root base of the clump is bigger and strong enough to support more culms. They should be well spaced so that harvesting is easy.

NEW SHOOT CUTTING AND MARKING

During the shoot season it is easy to maintain your clump. When the clump starts to grow new shoots, choose shoots that are healthy and in a good position, and allow six to eight of these to grow. Chop out all the others. By cutting the shoots you stimulate the growth of other shoots, so there will be plenty of shoots to choose from. The shoots you cut out can be used as food for people or animals.

Mark the shoots each year (once they are big enough), so that you know how old they are. This is because all culms should be three or more years old (bigger bamboos should be four years or more) before they are harvested. Then culms are stronger, suffer fewer borer attacks and last a lot longer!

Take a sharp knife or a nail and mark the culm, when it has reached full height but before it has any leaves, and at end of the wet season. This leaves a permanent tattoo. Mark all the shoots at the same height (eye height is good) with the year they have grown. For example, for the year 2015, mark the culms '15'. They will be ready for harvest in 2018 or 2019. In 2018 you will know that any culm with 15 on it is definitely three years old. In 2016 mark them with '16', and so on.

Growing bamboo for edible shoots

Bamboo shoots are eaten in many countries and are a valuable source of fibre, vitamins and minerals. Many species of bamboo are edible, but some taste much better than others.

Growing bamboo for maximum shoot production is different to growing it for culms. Only let a few shoots grow each year so you do not have as many culms, and the clump is very open and easy to harvest.

Do not start harvesting shoots to eat until the bamboo plant is at least three years old. Before this time cutting shoots can damage the root system and will slow growth.

It is the one year old culms that produce the most shoots and so try to keep about four of these each year and about four two year old culms to keep the clump strong and healthy. Older culms do not contribute to shoot production, and make harvesting the shoots more difficult.

Some types of bamboo are good for culms and for edible shoots. If you are growing bamboo for culms, you will still be able to harvest some shoots for eating. However, if you are managing a clump for shoots, there will not be a culm harvest, but you will harvest many more shoots.

Bamboo plantations

It is difficult to manage bamboo clumps when they are growing wild in the forest. It is much easier when you grow the bamboo near your house, or as part of a managed system.

A bamboo plantation is the most efficient way to produce high quality bamboo. A bamboo plantation produces much more than just bamboo culms. It can also produce shoots for eating, leaves for animal food, and bamboo charcoal or wood for cooking and soil improvement. The bamboo can be planted so that it is a windbreak, a fence or for erosion control.

INTENSIVE PLANTATIONS

An intensive bamboo plantation is when bamboo is the main crop. It is best to plant large bamboo in rows with four to six metres between the clumps and eight to ten metres between the rows. On sloped land plant the bamboo following the contour. Leaving eight to ten metres between the rows gives you plenty of room at harvest time to cut and collect the culms.

If you are growing for maximum shoot production for food, the clumps can be planted closer together and the rows can be four to six metres apart. Fertilise along the rows to encourage the clumps to shoot within the rows. Over time you will end up with continuous rows of bamboo rather than individual clumps.

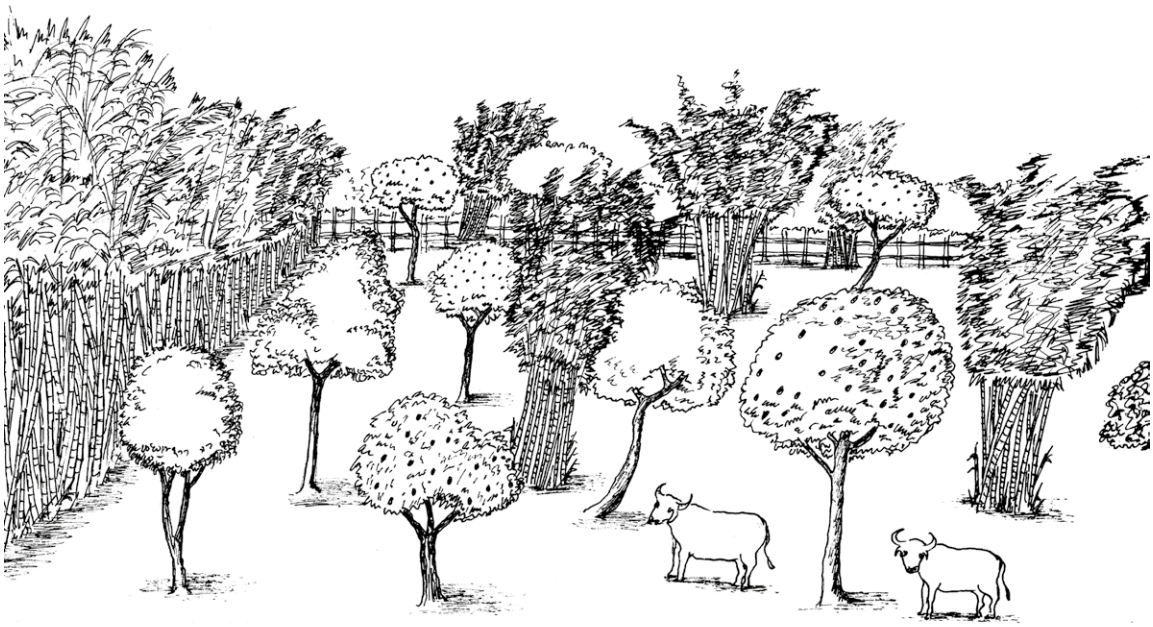
You can also plant annual crops between the rows while the bamboo is establishing itself. It is not a good idea to graze large animals in this area unless you can protect the bamboo; grazing animals love to eat bamboo, especially the new shoots.

MIXED PLANTATIONS

These are plantations where the bamboo is one of many crops. For example:

- A coffee plantation can have bamboo marking the boundary or as a windbreak.
- Rows of bamboo 20 to 25 metres apart are grown with coffee, bananas, citrus, other fruit trees and even annual crops in between.
- Bamboo is mixed with tree crops that are a similar height to the bamboo: e.g. mangos, coconuts, avocados, jackfruit, oil trees, timber trees, fibre trees and many more.
- Animals can be added to the system if they are well managed.
- A row of bamboo is planted on the contour of a hill to prevent and block any landslides or stabilise the edge of a terrace.

The combinations of trees and bamboo you grow together are up to you, but remember to leave enough room for bamboo culm harvesting.



How to harvest high quality bamboo culms

1. Select the right species for the specific conditions.
2. Harvest the culms at the right age
3. Harvest the culms at the right time.
4. Cure and store the culms well.
5. Preserve the culms against borers and fungus (if possible). Borers are insects that eat bamboo once it is harvested.

1. The right species

Some bamboos are naturally stronger and more resistant to borers than others. Ask local bamboo craft workers, bamboo experts or research to find the best species for your area.

Here is a list of species that grow well throughout the tropics and have good borer resistance. The list starts with the largest to the smallest culm diameter:

- *Dendrocalamus asper* (giant bamboo): (there are a few varieties, the Indonesian "Betun" is the largest), edible shoots
- *Gigantochloa pseudoarundinacea* (maxima bamboo)
- *Dendrocalamus brandisii* (velvet leaf bamboo): edible shoots
- *Bambusa oldhamii* (giant timber bamboo): drought tolerant, edible shoots
- *Dendrocalamus strictus* (solid bamboo): drought tolerant, edible shoots
- *Gigantochloa atter* (sweet bamboo): thin culm walls good for making wall panels, edible shoots
- *Bambusa tulda* (Bengali bamboo): solid culms
- *Bambusa blumeana* (thorny bamboo): incredibly tough, has many thorns, edible shoots
- *Gigantochloa apus* (string bamboo)
- *Bambusa polymorpha* (Burmese bamboo): solid culms

Another important variety is Guadua spp., grown throughout the South American tropics.

There are many other species, so research and choose the varieties that best suit your climate, land and needs. However, make sure the bamboo is resistant to borers!

2. The age of bamboo

THE AGE OF THE BAMBOO CLUMP

The clump needs to be at least five years old before you have culms that are old enough to be good quality. These culms will have a smaller diameter but will increase in size every year until the clump is eight years old, which is when continual production of full sized, good quality culms begins.

THE AGE OF THE CULMS

When you harvest the culms they must have been growing for at least three years. For some larger species, four or five year old culms are better.

When bamboo culms are one or two years old they contain a lot of starch (compound sugar), which is soft and what borers love to eat. After three years there is a lot less starch and the wood is harder.

Bamboo harvested younger than three years old will shrink and crack and have more borer attacks. Bamboo that is harvested from three years old lasts **many years** longer, has fewer borers and is stronger.

Ideas for identifying the age of culms:

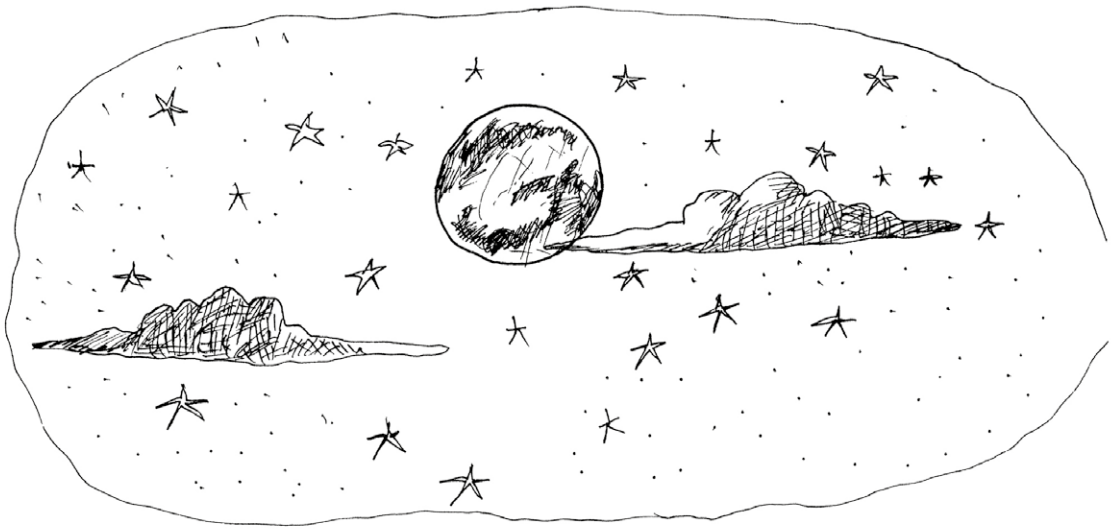
- Fungus and lichen on the culms: it takes a number of years for these to grow.
- New culms are shiny (or hairy) and still have some culm sheaths at the base.
- Development of side branches: bamboo grows a main branch in the first year and side branches in the years afterwards.
- Dead lower branches (older culms)
- The most accurate way is to look at the end of the branches and see how many leaf scars there are. This is the point where the old leaf–a new one is formed each year–has grown, then died. Therefore a two year old culm has one leaf scar, a three year old culm has two leaf scars and a four year old culm has three leaf scars.
- If you have marked the year that the shoot came up, you will definitely know. This is the best way.

Counting leaf scars to identify the age of culms

3. Harvest time

The best time to harvest bamboo is during the dry season.

The very best time is when the new shoots are almost at their maximum height and are just beginning to develop branches and leaves at the top. At this time the older culms have the least starch. People from some cultures harvest bamboo according to the moon cycle. At the new moon the energy of the plant is in the roots, so there will be less sugar in the culms; therefore less to attract the borers. Scientific evidence shows that this is not as important as the time of year. Combine both ideas for the best results.



4. Natural preservation of the culms

Borers and fungus are the biggest problems with bamboo.

You need to preserve the bamboo so that it will not be attacked. It is important to understand how the borer works. Borers are small flying beetles that lay their eggs on any part of the bamboo where the skin has been damaged. This is usually happens at the cut ends, where the branches have been removed and the skin scratched. The eggs hatch at different times and the borer eats the starch (compound sugar) in the bamboo. Therefore, a lot of borer attacks can be prevented by good management and by not scratching or damaging the culms.

Whoops! Forgot to preserve the bamboo!

The first step in preserving bamboo is to reduce the amount of starch. Only harvest bamboo in the dry season and only culms of three years or older because the amount of starch is lowest. The next step is to reduce the starch content even further.

This can be done in many different ways.

CLUMP CURING

The culms are cut and left in the clump for four to six weeks until the leaves have fallen off. The culm needs to be lifted onto a rock to keep it off the ground. The drying leaves use up a lot of the starch and the culm dries slowly without any damaged areas for the borers to lay their eggs.

WATER TREATMENT

The culms can be laid in fresh running water for two to three weeks. Remove all the branches and knock out the nodes in the middle of the bamboo culms so the water can flow through. The water removes most of the starch. After the water treatment the culms must be dried slowly in the shade. If they are left in the sun they will crack. It is best to dry them standing up if you can.

SEAWATER TREATMENT

A common way to treat bamboo is with seawater. One method, for coastal communities, is to put the bamboo in the ocean. Tie it down very securely with rocks, so that it does not float or move with the tides. Do not let the bamboo be exposed at low tides or it will crack.

Another, perhaps easier, method is to dig out a soakage pit on land near the ocean. The pit will naturally fill with sea water as you dig down below sea level. Dig the pit below the low tide level or the bamboo will crack. For both methods, leave the bamboo for two weeks. Then leave it to dry, off the ground, in a shady place.

DERRIS TREATMENT

Derris is a plant found in many tropical countries. The roots are often pounded and put into water holes to kill fish. Derris is poisonous to fish and amphibians, and must be used with care. To use the derris, make a solution of one bucket of pounded derris root and stem to 200 litres of water.

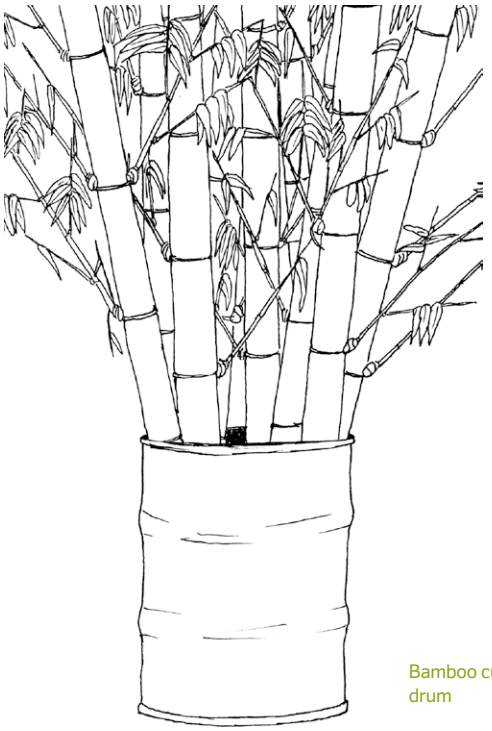
You can use a drum or a tank for treating the bamboo.

Short pieces of bamboo can be cured in a drum. You can place the culms of bamboo that have just been cut in a drum with the leaves still on. The liquid in the drum will be drawn up through the culm to the leaves, and the culm will be treated by the derris.

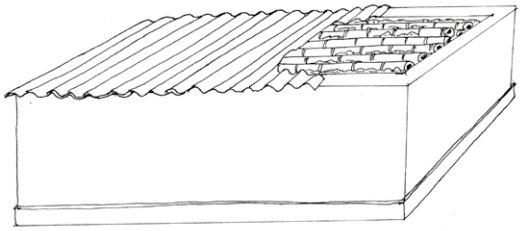
Add more derris liquid to the drum as needed, and leave for one week. Then remove the leaves and dry the culms in the shade and off the ground.

You can have the tank above or in the ground, but it must be covered from the rain and to stop children or animals getting in. The bamboo needs to be cut to length and have the branches removed. Place the culms in the tank for four to six weeks. Then you dry it in the shade and it is ready for use. If you use the water treatment first, the derris treatment will only take two weeks.

Any liquid that is left over can be used to spray aphids or caterpillars on crops, or it can be diluted and poured onto the ground **well away** from any rivers, ponds or other water.



Bamboo curing drum



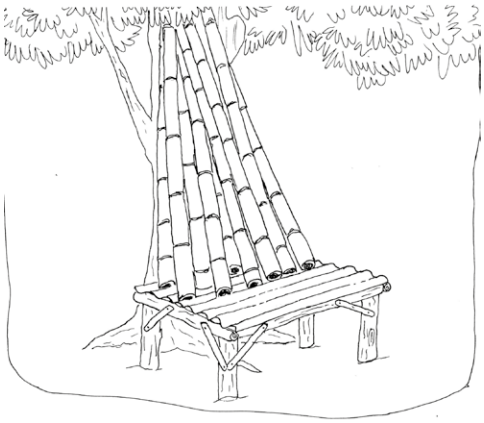
Bamboo curing tank

BORON TREATMENT

Bamboo can also be treated with boron. It is a natural product that kills borers and their eggs. Boron is best for quickly treating large amounts of bamboo, especially for that grown for export. Most countries will not import bamboo that has not been treated with borax or other chemicals. The bamboo is put into a water and borax solution for two weeks, and then dried in the shade and off the ground. Instructions for treating bamboo with boron are in the bamboo section of the reference chapter.

Careful: Boron is natural, but it is very strong. Proper protective clothing must be worn, and people must wash thoroughly after working with the boron solution.

The boron solution must be disposed of carefully. If it is diluted with water, it can be put around fruit trees. Spread it as widely as possible. It has mild pesticide and herbicide properties, and is a trace element that promotes root growth. If it is diluted to 0.1% (one part borax to 1,000 parts water) it can be put onto vegetable gardens. Do not dispose of it in a river or near any ponds or water.

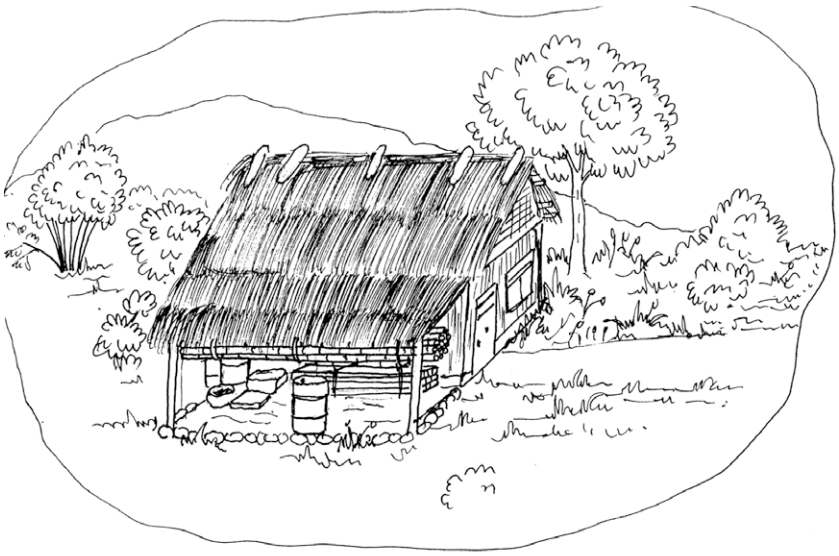


Drying cured bamboo culms

5. Drying and storage

This is very important. Bamboo that is cured and stored well is stronger and lasts a lot longer.

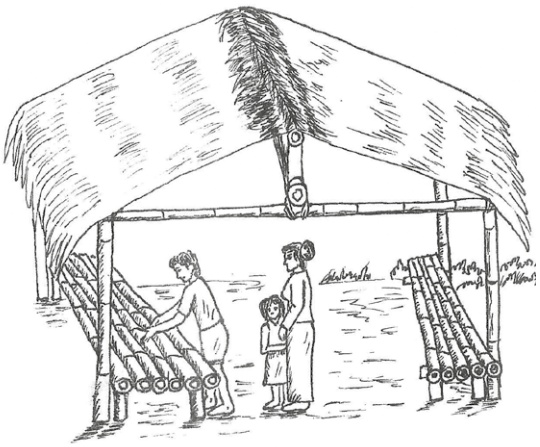
Bamboo takes four to six weeks to dry before it is ready for use. If it is stored vertically, it will be ready in four weeks, horizontally it takes eight weeks. It must be dried and stored in the shade, off the ground and, if possible, out of the rain. Storing bamboo out of the rain is not as important as keeping it in the shade. If you dry and store bamboo in the sun, it will crack and split.



Good bamboo storage: under shelter and off the ground

To produce high quality bamboo for building or craft products the best method is:

a. Harvest the year's supply of culms, three years or older, in the dry season.
b. Use clump curing or the water treatment.
c. Use the derris or borax treatment.
d. Dry the culms vertically in the shade and off the ground.
e. Store them off the ground, under a roof.
f. Inspect them regularly, and remove and burn any that have borers.



This way you will have a wonderful supply of high quality bamboo to use throughout the year to make beautiful, long lasting buildings and products.

OIL AND VARNISH

Oil and varnish is the final step to prevent fungus and rot, and extend the life of the product once the bamboo becomes a piece of furniture or craft item, for example. It is especially important to oil or varnish the ends of bamboo or any other cut areas. For the best results, use sand paper (lightly) first to enable the bamboo skin to bond with the varnish. If you add citrus skin to the oil, and let the oil sit in the sun for a few days, it helps to prevent mould on the bamboo.

It also increases the value of your product.

Bamboo products

Building bamboo structures

Bamboo can be used to make houses, walls, floors, roofs, animal houses and much more. It is strong, lightweight and easy to use. Bamboo is also very decorative and can be used to make a house more beautiful.

There are many ways to use the bamboo. A simple method is to split the bamboo culms into halves and flatten each half. Another method is to make woven panels. For more permanent structures, whole culms can be used. Large culms can create the structure too. The style you choose depends on how much bamboo you have and what you are building. There are many, many different designs and methods, too many for this guidebook! We can explain just a few simple techniques that help a lot when using bamboo.

For specific techniques, look in the reference section of this manual for groups, books and websites.

There are a few simple things you can do to improve the lifespan of bamboo buildings:

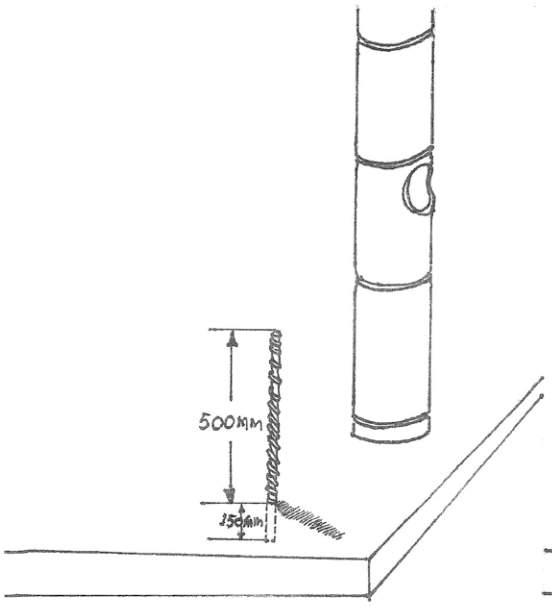
- Keep the bamboo off the ground, on concrete or stone footings.
- Keep it dry.
- Keep it out of the sun.
- Use well harvested, cured and preserved bamboo.
- Oil or seal the cut ends of the bamboo.

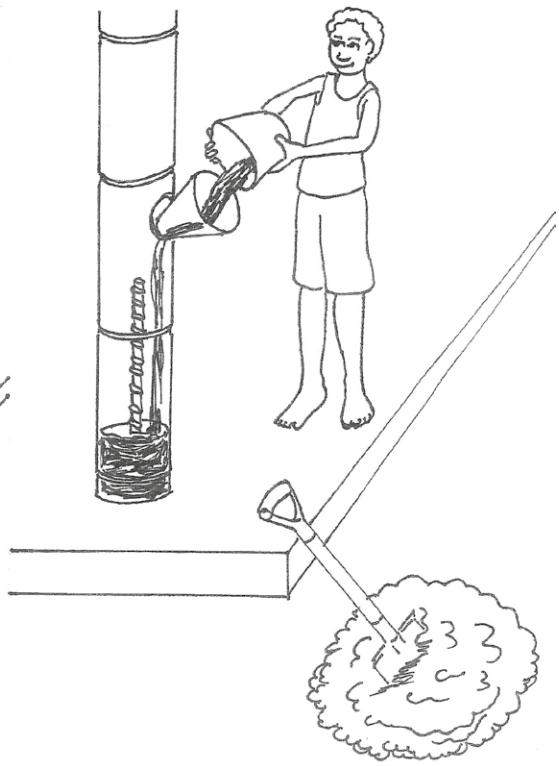
SECURING BAMBOO TO CONCRETE FOOTINGS

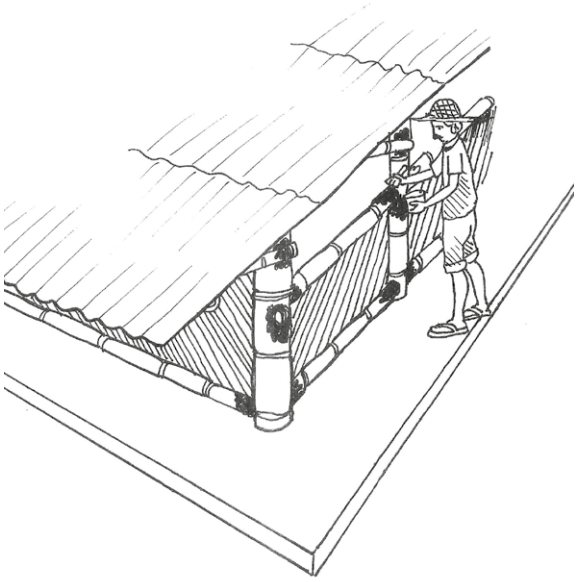
There are fungi and termites in the soil that destroy bamboo if they infect it. A simple way to prevent this is to use concrete or stone footings.

For concrete:

- Set a piece of 12mm metal bar (long enough to go through the two bottom nodes of the bamboo, the average is 500mm) into the footings where you are going to put a culm.
- Drill or cut a 30 mm hole in the side of the bamboo, above the end of the metal bar.
- Stand the culm over the metal bar.
- Make a concrete mix of two parts sand to one part cement, and pour it through the hole until full. You can also use concrete in the same way, to reinforce joints in the building if they are bolted together.





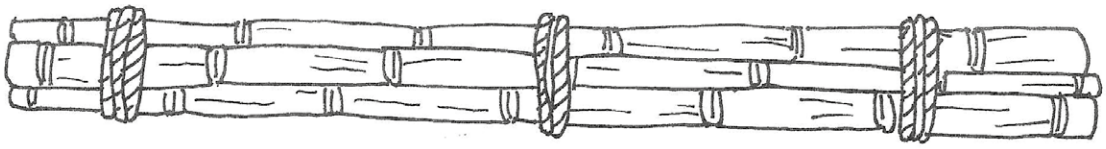


- Keep the bamboo dry and out of the sun.
- Make sure that the roof is wide enough to protect any bamboo on the outside of the building.
- Use well harvested, cured and preserved bamboo. See earlier in this chapter.
- Oiling or sealing the ends of the bamboo is really important as this is the weakest part, where water or fungus can get in.

Sealing joins to prevent insect or disease problems

COMPOUND POLES

Sometimes you might not have big enough culms for your building needs. You can bind several culms together to make a compound pole or beam. It is important to bundle them up so you have a mix of bottoms and tops together at each end: the strength is then evenly spread.

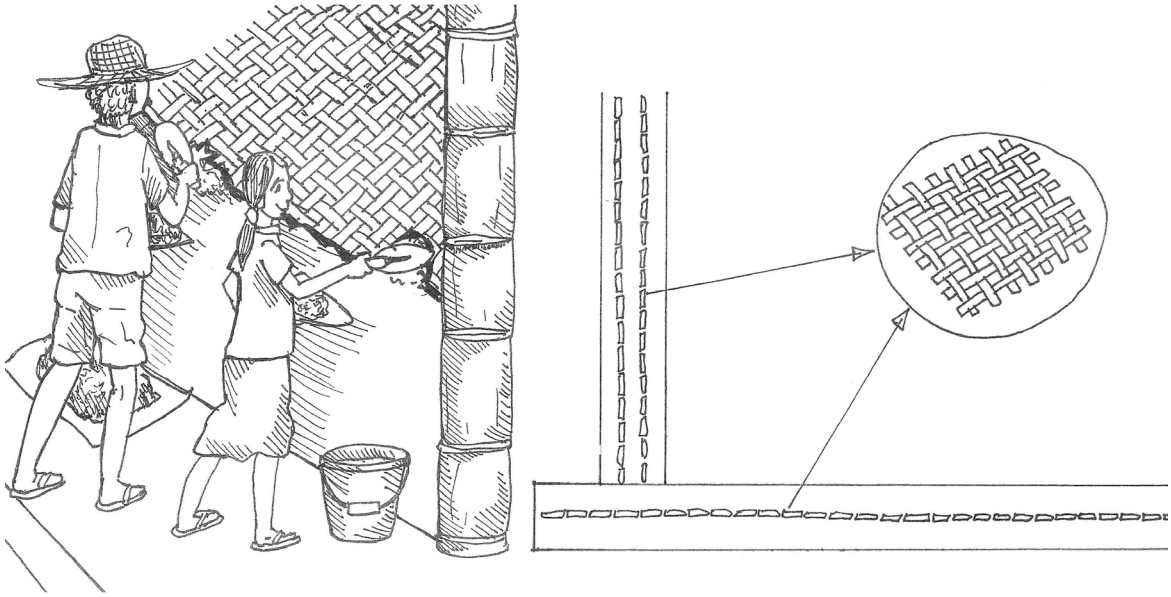


BAMBOO REINFORCED CONCRETE

Woven bamboo panels can be used instead of metal bars to reinforce concrete floors, walls or benches. Using bamboo rather than metal makes it cheaper and lighter, and the bamboo is flexible so the walls are safer during an earthquake.

Walls and benches: the panels need to be woven to have 40 to 50 mm gaps, and then rendered with a few layers of concrete. Initially it is hard to get the cement to stick to the bamboo, but after the first layer it is easy to add more. It is easier to use two panels for walls, so the concrete is caught between them.

Floors: bamboo can also be used to reinforce concrete floors. The bamboo panels do not need to be woven as tightly as for walls



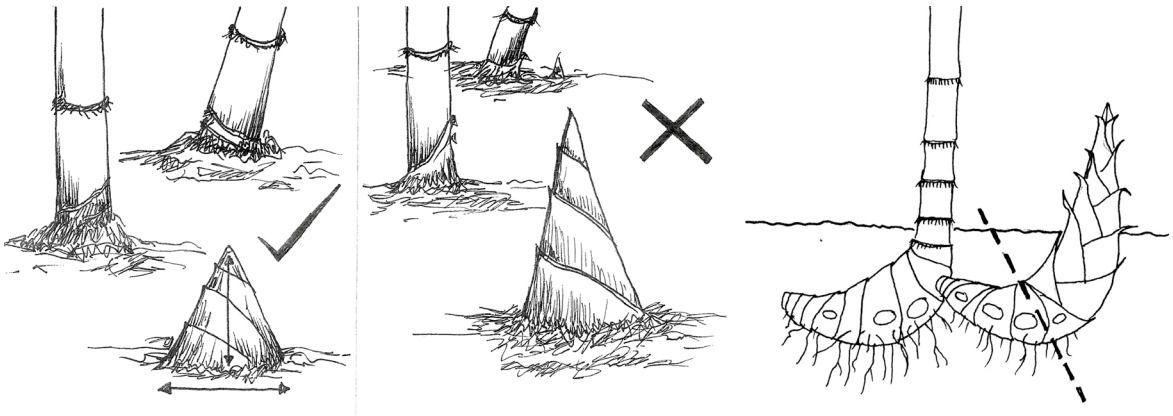
Food

FOOD FOR PEOPLE

Bamboo is a highly nutritious food that can be cooked in many ways. It is eaten a lot in China, Japan, Thailand, Indonesia and many other countries. Some types of bamboo produce shoots that can be eaten and some do not.

WHICH PART TO EAT?

In the wet season, new bamboo shoots grow, generally at the outer edge of the clump. When the shoot is as tall as it is wide at ground level, dig down and cut the new shoot from the old roots where the shoot becomes hard. If the shoot is any older, it will be too tough and bitter to eat.

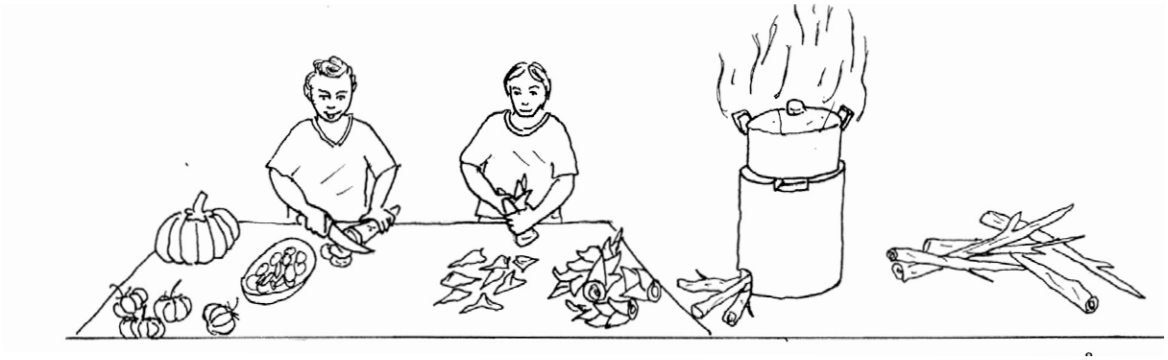


Bamboo shoot ready for eating

HOW TO EAT THE SHOOTS

Bamboo shoots need to be eaten fresh, within two to three days of harvest. Wash the shoots and peel or cut off the outer leaves until you have just the white flesh. Cut the shoots into thin slices or cubes.

1. Boil the shoots in water for 20 to 30 minutes. If the bamboo shoots are too bitter, rinse the water and cook them again for the same amount of time. If you cook rice with the bamboo shoots, it helps to reduce the bitter taste. Once the shoots are cooked, you can store them in fresh water to use as required.
2. The boiled shoots can be cut up and fried in a little oil with garlic and red onions.
3. They can be stir fried with mixed vegetables. They take on the flavours of the dish and stay crunchy, so add them early in the cooking process.
4. There are many other ways to cook them, just use your imagination!



Bamboo shoots can also be pickled, dried or fermented to last longer.

FOOD FOR ANIMALS

Bamboo shoots also make excellent animal food, especially for pigs. Cut the shoots the same way as if cooking for people, and combine them with other food for animals – cassava, sweet potato, yams, leaves, and so on. Bamboo leaves and young stalks are also high quality animal food, particularly for goats and cows, which benefit from the silica content, because it improves milk production and breeding. They are a great supplement feed for improving the health of horses.

House and market products

BAMBOO PLYWOOD, LAMINATED PANELS AND BEAMS (STRUCTURAL BUILDING MATERIAL)

Bamboo can be made into plywood or laminated beams that reduce the need to cut down trees for building. The bamboo is split into strips and treated with boron. These are planed to an even thickness, laid in the required form with glue, then pressed. The laminated panels are very strong and lightweight and can be used to create beautiful, long-lasting furniture.

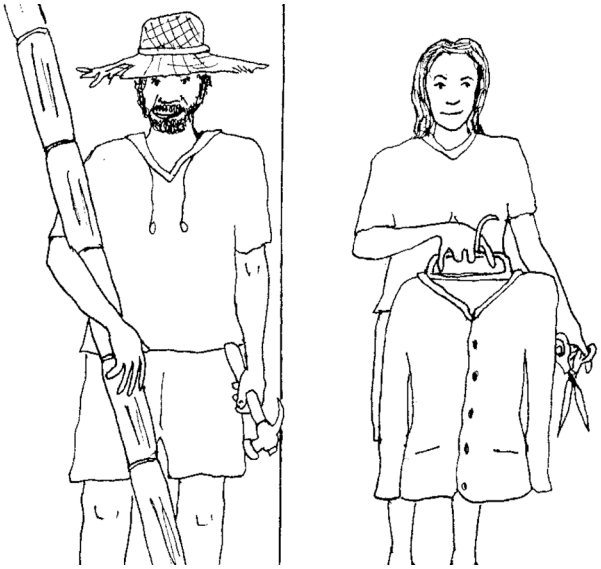
FURNITURE BUILDING MATERIALS

Bamboo furniture is beautiful and long lasting if treated bamboo is used. It can be a good way to make money. Chairs, tables, beds, wall panels, shelves and much more can be made from bamboo. To learn and build furniture requires training, some tools and imagination. Look in the reference section for more information.

CLOTHING

Bamboo clothing is becoming more and more popular. It is long lasting and very comfortable. Compared to cotton, it is cooler in hot weather and warmer in cold weather. Making bamboo clothing requires machinery and a good bamboo plantation for a constant supply. It is achievable as a cooperative, business or government initiative.

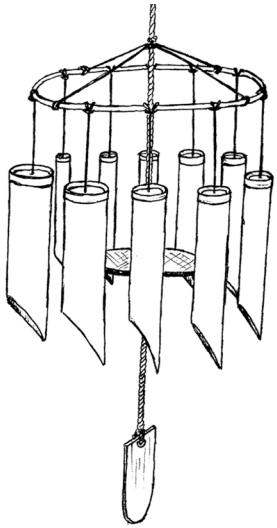
IMPORTANT: there are two ways to make bamboo fibre for clothing: one uses a lot of toxic chemicals, and the other is very sustainable and good for the environment. Research the different techniques.



MUSICAL INSTRUMENTS

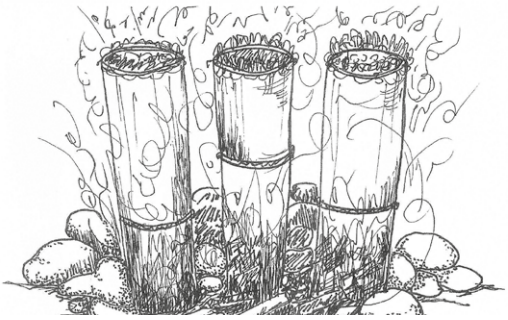
Bamboo can be used to make many different musical instruments:

- Flutes
- Pipes
- Wind chimes
- Shakers
- Indonesian gamelan — traditional music ensembles consisting mainly of percussive instruments
- Drums
- Lakadou — traditional Timorese percussion instrument
- Traditional mouth harps



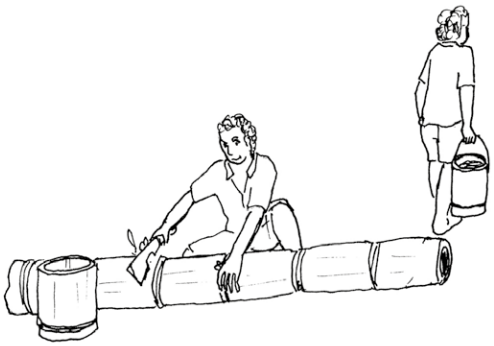
COOKING CONTAINERS

Freshly cut bamboo culm sections can be used as cooking containers for meats and soups on open fires. A traditional method in Timor-Leste, called tukir, uses green bamboo, which does not burn, and the used pot becomes mulch or compost afterwards.



WATER CONTAINERS

Large bamboo culms can be easily cut up and used to make buckets and watering containers, attaching wire handles. Used traditionally before plastic buckets, they last much longer and create no pollution or waste. They last much longer if they are oiled before use.



STORAGE CONTAINERS

Bamboo culms can be cut into sections and used to make storage containers for seeds, food, jewellery, pens, pencils, knives, forks, spoons, hair ties, money, sewing goods, lighters and much more.

Open containers can even be used for dried flowers or candle holders.

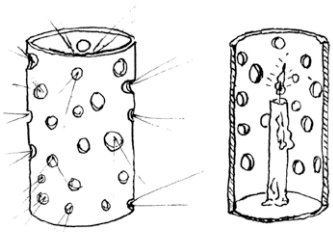
The containers can be carved, painted and decorated and made into a good product to sell.

They will last much longer if the bamboo is treated and oiled. If the containers are used for seeds, including beans, corn or rice, the bamboo **must** be treated to stop borers in the bamboo eating the seeds. **do not** store seeds for eating in bamboo treated with boron.

PLANT CONTAINERS

Large and small bamboo culms can be cut to make plant containers. Do not forget to put some small holes in the bottom to let the water drain out. Small culms can be cut into sections and used in nurseries for seedlings and young trees. Large culms can be cut into sections and used for flowers and plants around the house. Long sections of large culms can also be used.

CANDLE AND LIGHT HOLDERS

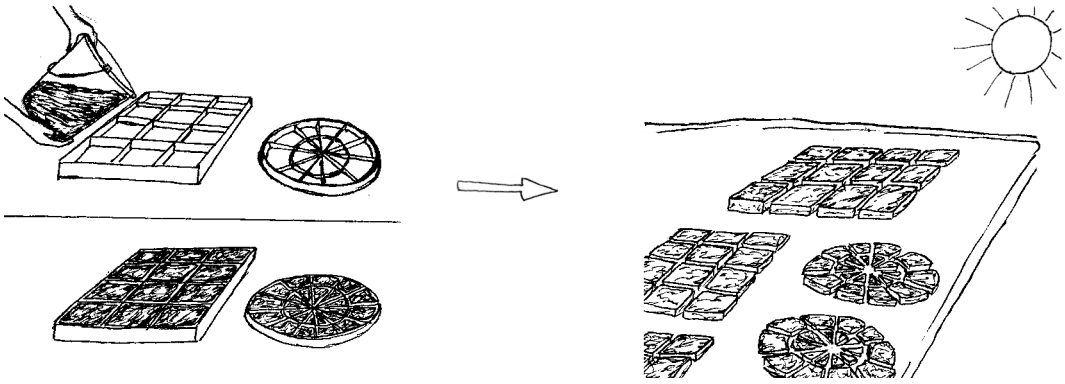


Bamboo sections carved with patterns that let light through make beautiful candle holders and can also be used for light fittings. Use wide culms so they do not get too hot and start burning!

BAMBOO CHARCOAL AND WASTE BRICKS FOR COOKING

Charcoal bricks can be made for cooking instead of wood. It is a mix of burnt bamboo pieces–charcoal–and a small amount of arrowroot powder and water. It is much easier than collecting firewood! The dry bricks burn well and do not produce much smoke. Read Food, health and nutrition (**Ch 8**) for how to make them.

Bamboo waste bricks are made from all the bamboo sawdust left over from making products. A simple machine turns it into compressed bricks that burn slowly and replace wood in cooking stoves. This is an important part of any bamboo product cooperative or initiative.

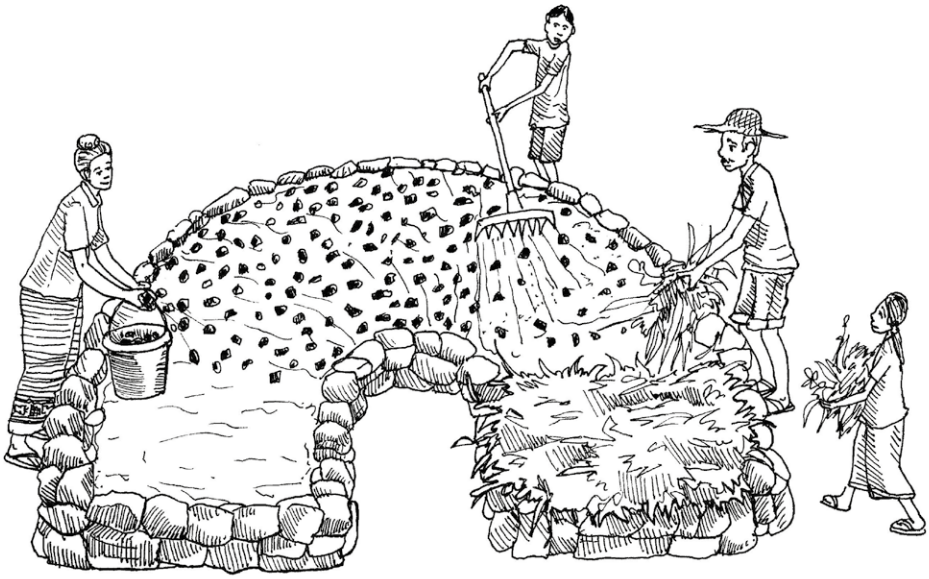


Bamboo farm products and functions

Bamboo biochar

Biochar is charcoal that is activated with trillions of micro-organisms and nutrients then added to soils to improve them, and so food production. The charcoal provides carbon, holds nutrients and provides a place for the micro-organisms to multiply. This enables a year round nutrient supply and a big increase in production and water storage capacity in the soil. See Soils (**Ch 9**) for more.

Bamboo is the best material to make the charcoal because it has a larger surface area and can hold more micro-organisms. It also contains silica, grows quickly and is much more sustainable than wood.



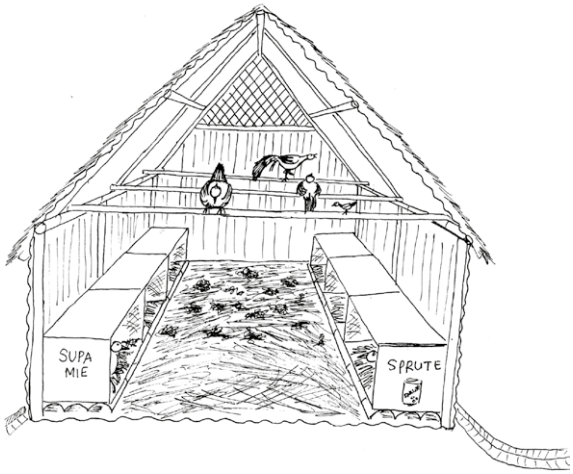
Bamboo leaves

MULCH

The leaves are a great long-term mulch and weed suppressant. They are high in silica, and this improves and strengthens any fruit trees or vegetables.

CHICKEN NEST MATERIAL

Bamboo leaves are also great nesting material for chickens as they help deter mites.



COMPOST AND LIQUID COMPOST MATERIAL

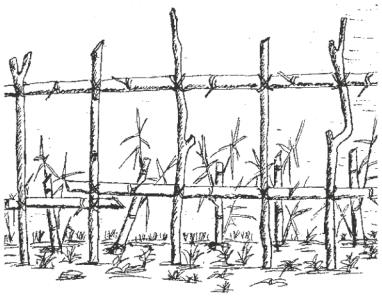
Bamboo leaves are excellent material for composts and liquid composts because they contain silica and break down quickly. Green bamboo leaves contribute significant nitrogen and potassium but are low in phosphorus, so add extra bird manure to composts made with lots of bamboo leaves.

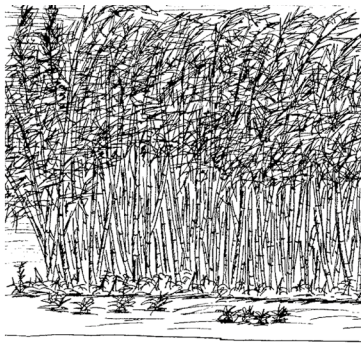
Bamboo ash for gardens

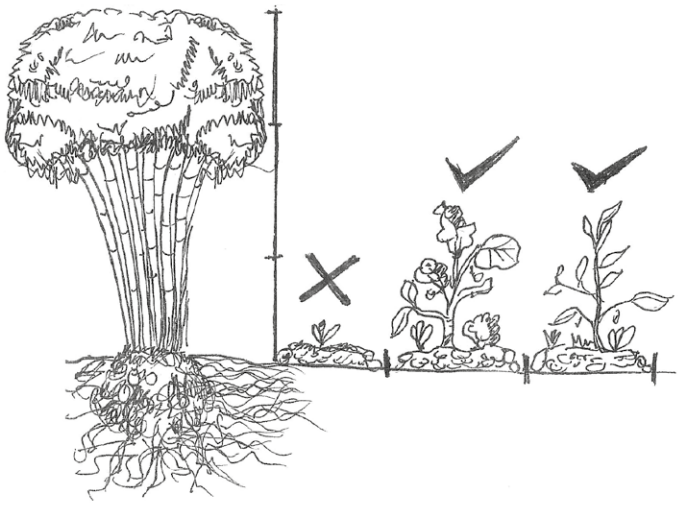
Whenever bamboo is burnt, it is important to use the ash and any charcoal on the garden. It is high in potassium and is pH neutral. Use a handful per square metre. When the charcoal is dug into the soil, it increases the numbers of healthy micro-organisms.

Living fences

Bamboo plants make an excellent living fence. It takes a few years to become thick enough so you need to build a temporary fence. This is easily constructed with dried bamboo poles tied onto the growing culms. Bamboo living fences are excellent for animal yards including for chickens, ducks, cows, buffalo and pigs. They provide shade, some food and reduce wind. They can be used around orchards as part of an animal/orchard system. They are not good to plant close to vegetable crops or fruit trees because they take water and nutrients, and may give too much shade.



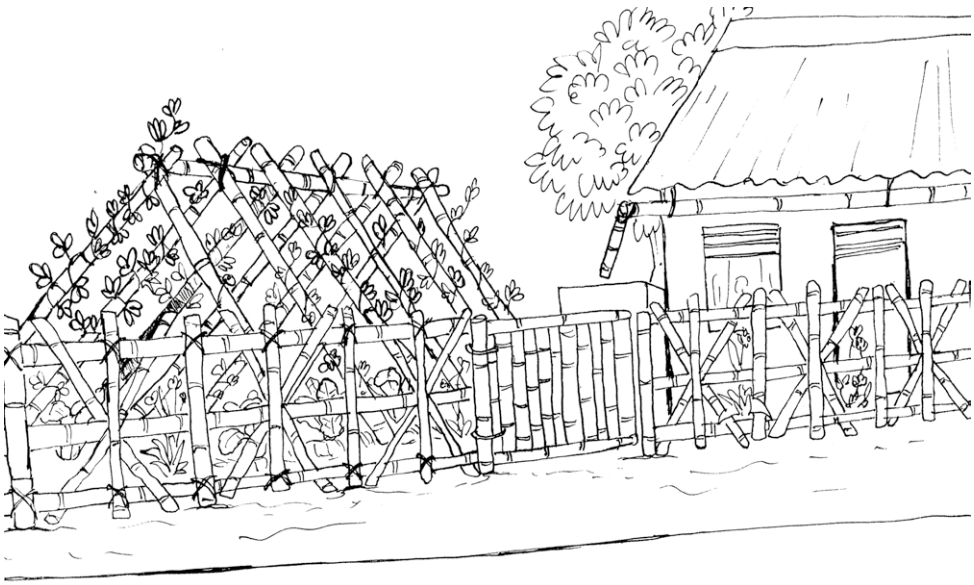




Important:
If you take the height of fully grown bamboo and divide it by three, that is the distance you need to allow from the bamboo before plants will grow and produce well.

Trellising

Trellising is important for increasing the amount of produce from the garden. Bamboo culms are easy to use for trellising because they are light and easy to move. They can be used to make any shape you want and can be very decorative, adding beauty to your garden.



Fencing materials and fences

Bamboo culms are used a lot for fences. It is best to use them as horizontal poles, not as posts, as they rot quickly in the ground.

COMPLETE BAMBOO FENCE

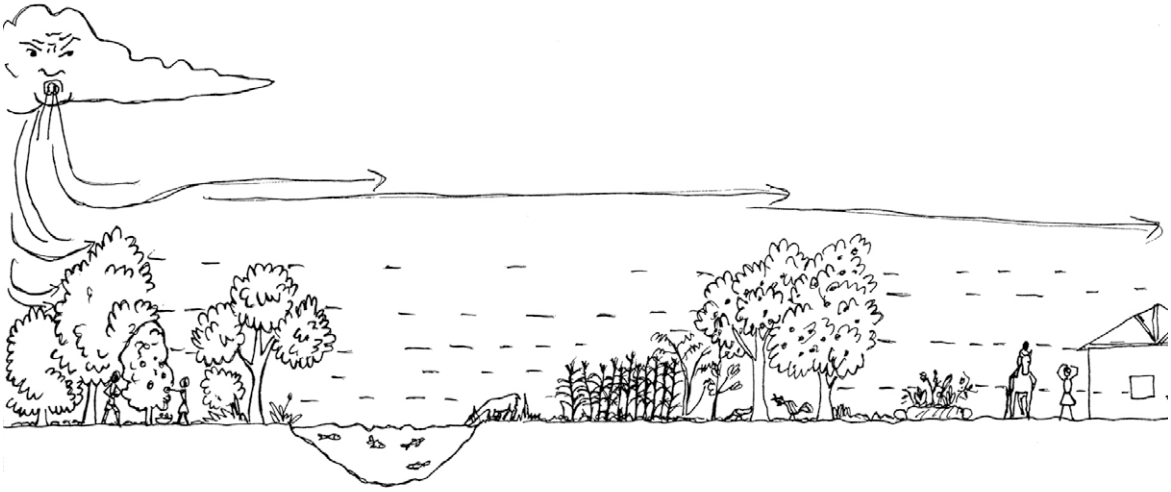
The tops and branches of bamboo can be made into fences with culms as horizontal poles. These last a very long time because borers do not eat these parts of the bamboo. This is a very strong fence that even goats do not want to jump over, and uses up the waste material from harvesting.

- Start with two sets of horizontal culms (top and bottom).
- Tie the culms to a post at one end.
- The branches or tops are fed in between the culms, and pushed down to the tied end.
- After about 20cm tie the two culms together to secure the branches.
- Continue, repeating the process.
- The posts can be living trees, wooden posts or whatever works best.
- The fence works better to stop goats jumping over if the top is uneven and uncut.

Windbreaks

Bamboo plants can be part of a large windbreak.

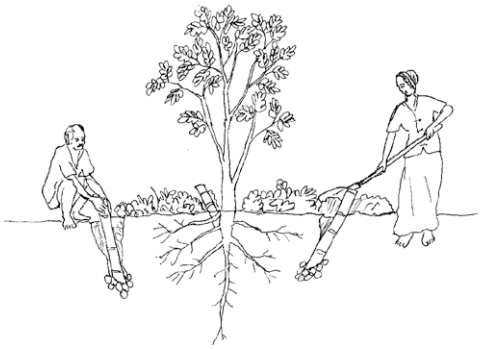
The bamboo eventually makes a fence as well if they are planted close together. Bamboo clumps can be used as a small windbreak to protect a house. Read Permaculture design strategies and techniques (**Ch 3**) for how to make a windbreak.



Irrigation pipes

There are many ways to use bamboo for irrigation.

- The bamboo can be split in half and used to run water from one place to another. This is very common and a great way to reduce the heavy job of carrying water.
- The culms can be cut into half to one metre long sections and dug into the ground to water fruit trees and vegetables. Put holes in the inner nodes to let the water through. This technique saves a lot of water and improves growth.
- Flat irrigation using long culms can be used for vegetables. This technique saves water and makes watering much easier. Read the Family gardens chapter (**Ch 10**) for more.



Erosion control, water bodies and reforestation

Bamboo is good to plant in areas where erosion is a problem. Choose varieties that can cope with tough conditions.

Bambusa vulgaris is one type of bamboo that is good for erosion control because it is very fast growing and spreads out nicely (it is an open clumping bamboo). It is also easy to propagate, drought and flood resistant, and the leaves are good fodder for animals. To reduce and prevent landslides, mix bamboo with trees that have deep tap roots.

SWALE SYSTEMS

Small bamboo is great to plant next to overflow points in swale systems to stabilise soils and prevent erosion and runoff.

RIVERS AND SPRINGS

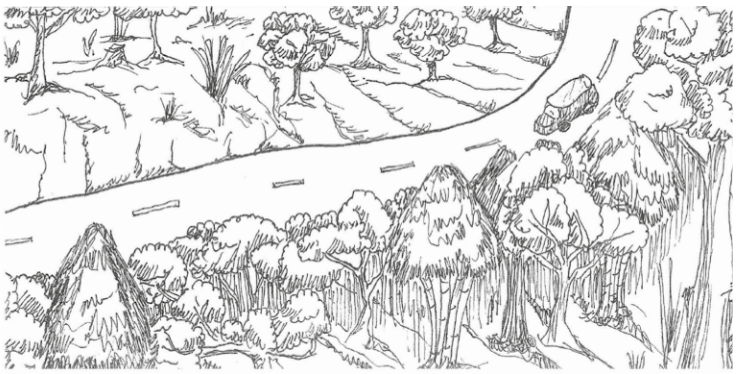
If bamboo is native to an area, it is ideal for planting around springs and next to rivers to prevent erosion and provide a habitat for birds and small animals.

WATER CHANNELS, PONDS AND AQUACULTURE

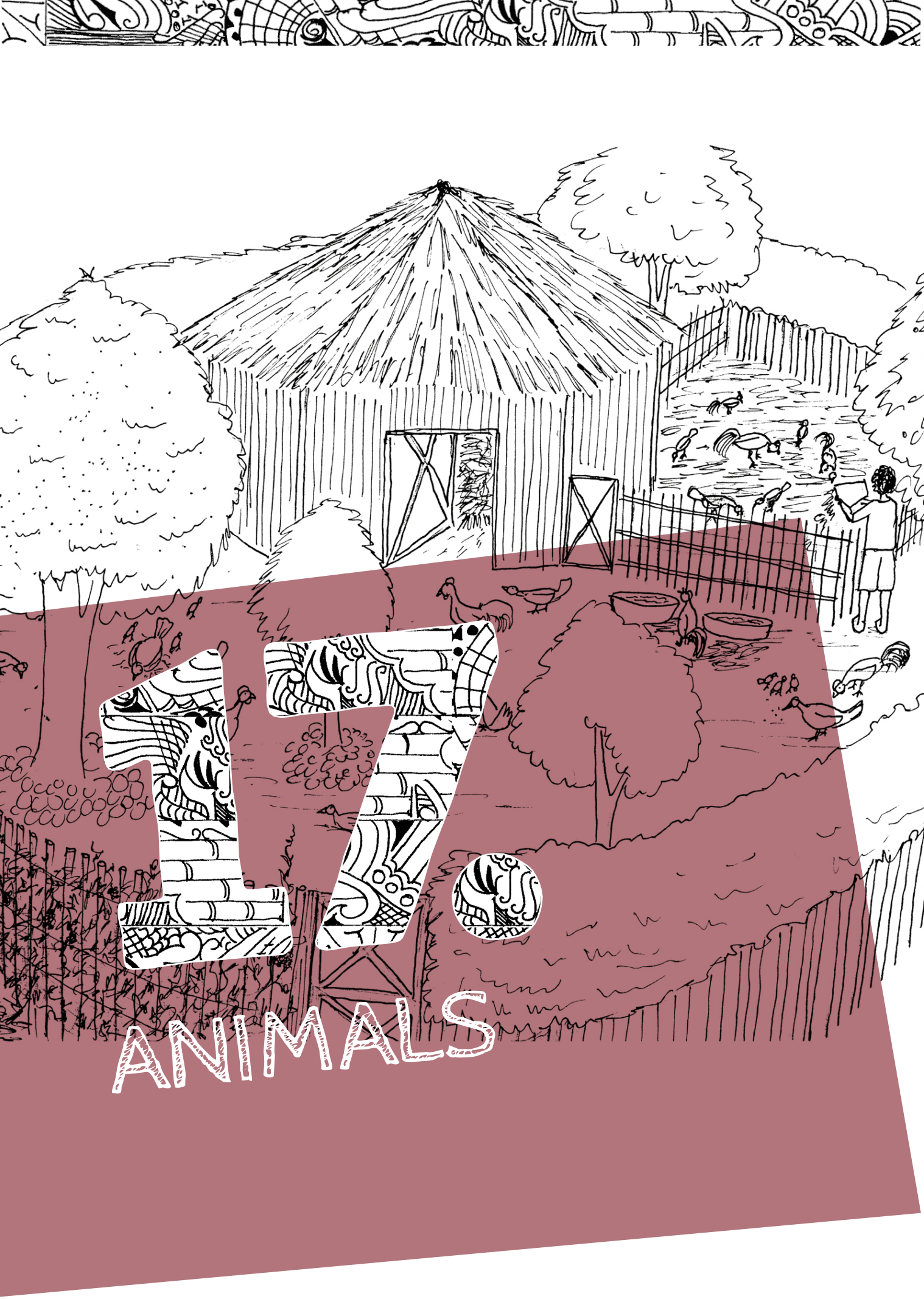
When bamboo is grown next to water systems it prevents erosion as well as providing shade. The leaves breakdown in the water to provide food for fish, and the silica in bamboo leaves is excellent for producing bigger prawns and crustaceans.

ROADS

Bamboo planted below roads on hillsides catches any soil washed off and stabilises the road. Bamboo is also strong enough to catch any cars or buses that might slip off the road!



BAMBOO
CHAPTER NOTES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17. ANIMALS

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This chapter looks at the different animals that people raise in tropical countries. It considers how to provide the food, housing and medicine needed for healthy animals using local and traditional materials and the appropriate modern technology. Raising animals using permaculture methods regenerates the land on which the animals are raised as well as the surrounding environment. This chapter also looks at different ways to integrate animals into agriculture, agro-forestry and aquaculture systems, and how to use their natural habits as productive labour.

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The importance of animals

Animals are very important for good health, a productive farm and prosperity.

Animals are:

- Sources of food, especially protein.
- A means of economic stability and a "living" bank.
- Labourers and provide transport.
- Providers of fertiliser.
- A part of traditional culture and ceremony.
- Sources of art and music materials.

Animals are part of almost every household and farm, and an integral element of most permaculture systems. It is important to manage them in a sustainable way, and to maximise their uses and benefits. Most importantly, they must be well cared for.

The best treatment for your animals is to look after them well and maintain their good health. Good quality food, water and a clean, comfortable house help to prevent many diseases and other problems. For new-born animals, providing them with food and water in a secure animal house and yard for a few weeks after their birth improves their survival rates, size and health **a lot**.

For all animals, make sure the breeding stock is healthy, of high quality and suitable for your region. Introduce new stock regularly to prevent inbreeding.

If the animals are healthy, happy and breeding well, they produce more meat/eggs/milk and babies. This improves the health of every person, as meat is an important part of meals, providing protein and other nutrients to help people grow and stay strong.

This chapter looks at houses and fencing examples for all animals and describes the benefits:

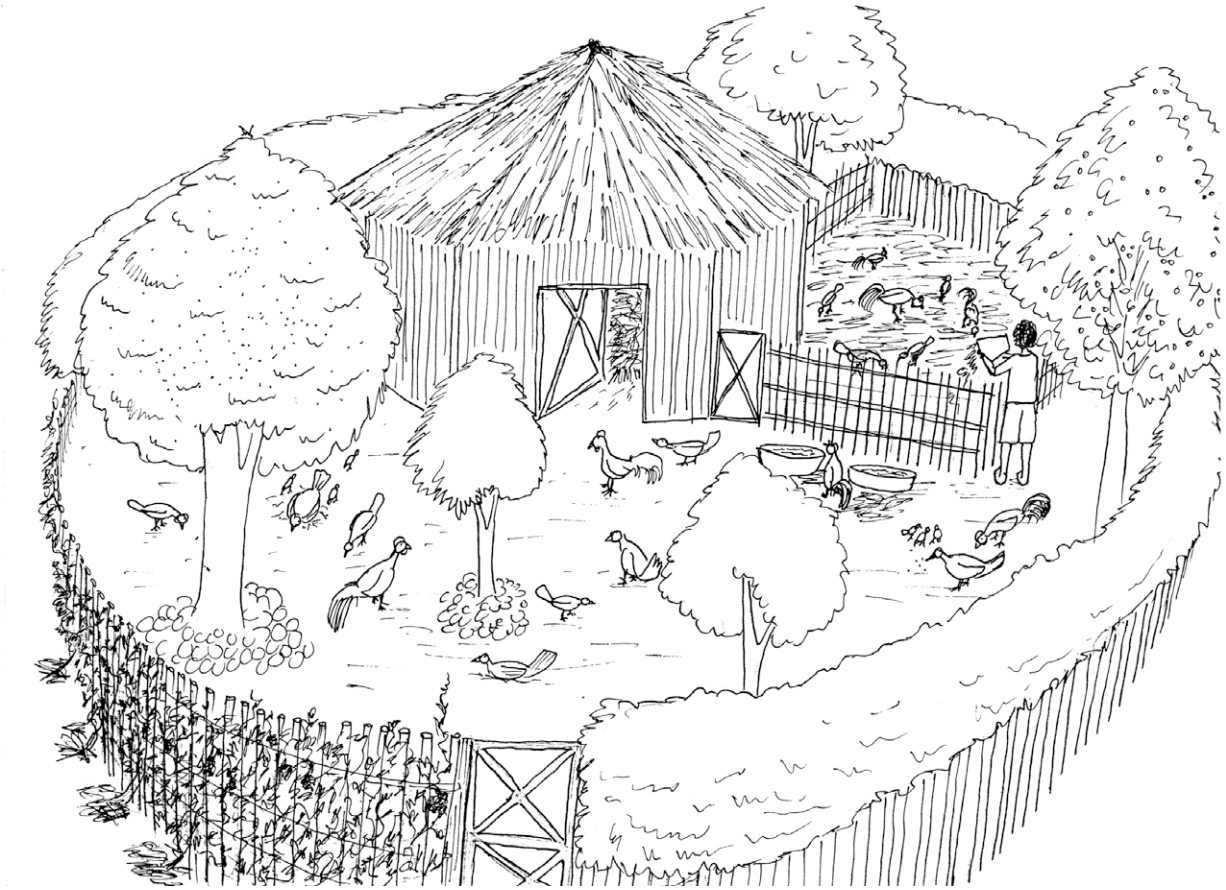
- Young animals are protected – more survive and they grow faster and bigger.
- Animal production and vegetables and fruit yields increase a lot when animals are fenced in and well looked after.
- High quality manure becomes easy to collect and a valuable product for trade.
- Fruit trees combined with animal systems produce much better.
- Animal health is easier to maintain.
- When animals are well managed, the surrounding environment is much healthier; rivers are less degraded, springs are preserved, and there is less erosion and more tree regeneration.

Small animals

Small animals are an important part of most permaculture systems, providing more benefits than larger animals.

This is because:

- Small animals breed more often.
- Small animals produce more meat on less land and use less food and water than large animals.
- Small animals have a **much** smaller impact on the land and environment.
- The animals provide meat as is needed, so no meat is potentially wasted.
- Chickens and ducks also provide eggs.
- Small animals contribute **much** less to creating climate change.

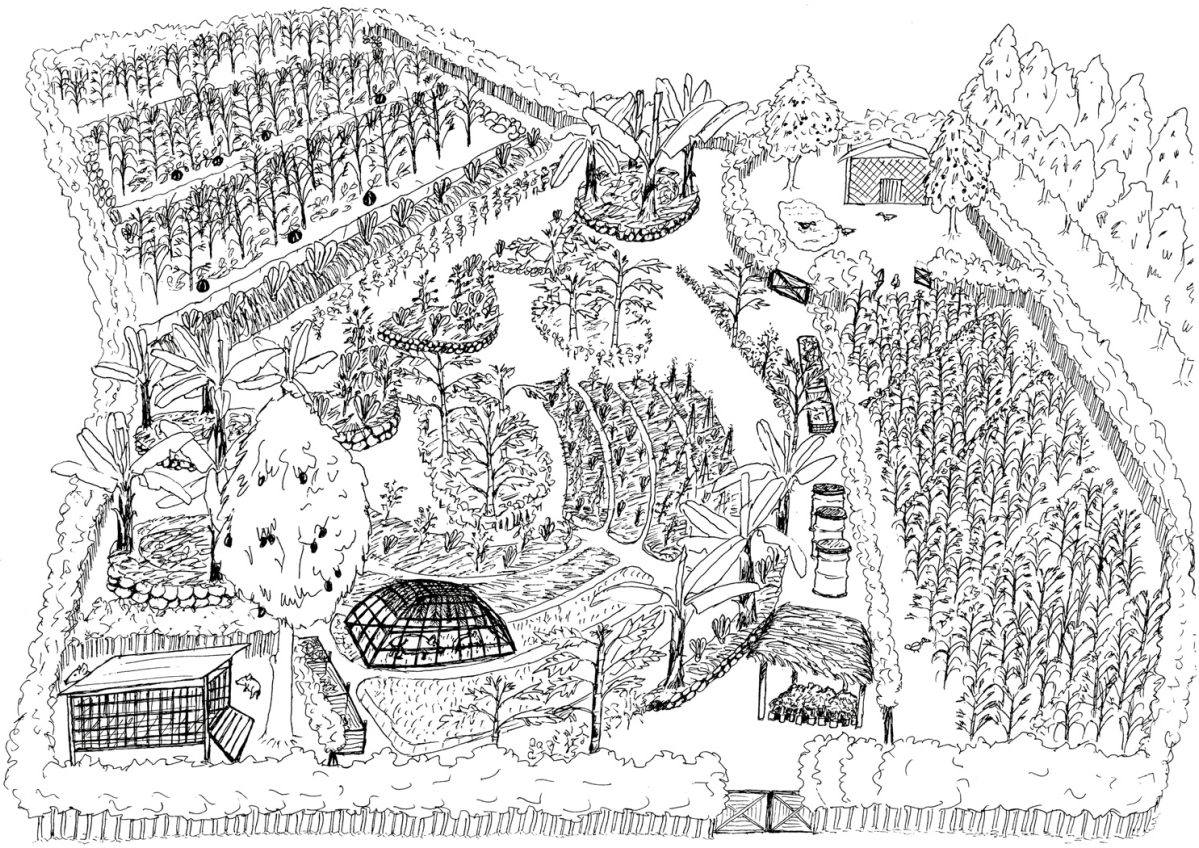


Animal system design

With the information presented here, you can start a new animal system or improve an existing system. It is also appropriate for animal systems that are managed by individuals or communities.

Raising animals using permaculture methods regenerates the land on which the animals are raised as well as the surrounding environment. Permaculture integrates these mostly self-maintaining systems with other food production systems, growing and making food and medicines for the animals instead of purchasing or importing them. All products are resources for other systems.

It is important to plant lots of trees to provide food, medicine, shade and fencing. By growing the food you need for your animals you create a sustainable and low-cost system. Growing trees for animal food ensures a more reliable supply; trees are more resilient to climate change and better for the environment.

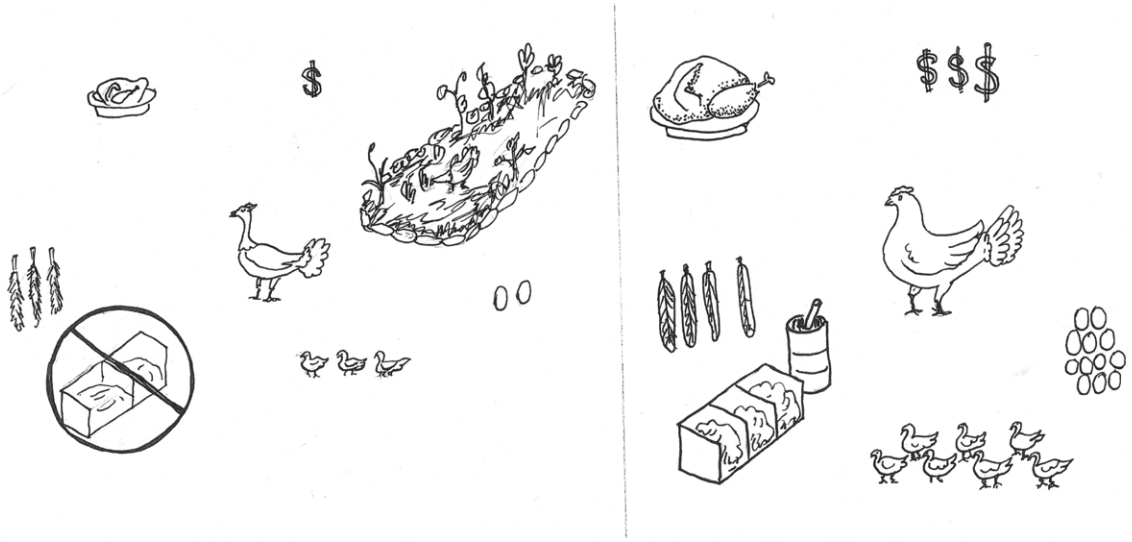


Animals integrated into family garden

Chickens

In many tropical countries, chickens usually roam freely and nest in trees or in bushes. This system is easy because it requires little maintenance. However, dogs, cats, rats and snakes eat many of the young chicks, and eggs are hard to find and can be eaten by other animals. The free roaming system means that people cannot collect chicken manure, a valuable fertiliser, and chickens are more likely to come into contact with other chickens that may carry disease.

When people allow chickens to go wherever they want they can destroy vegetable gardens, especially young plants. This makes growing food much more difficult and causes problems between neighbours.



Production from a free-roaming chicken compared to production from a well-managed chicken

A chicken house and yard keep the chickens in one place to:

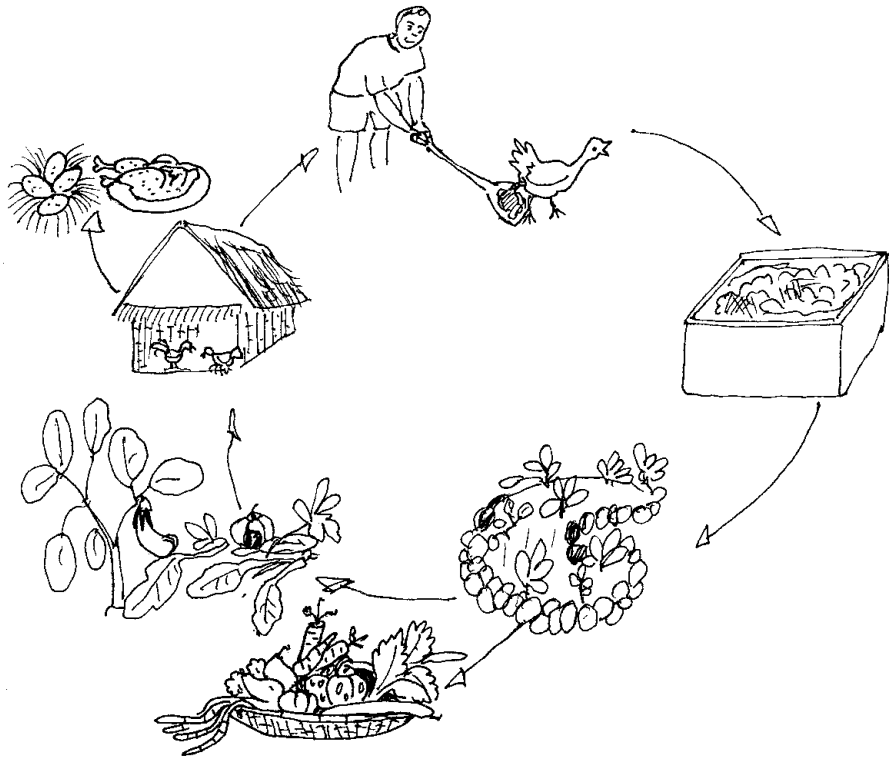
- Collect eggs and fertiliser.
- Protect young chickens.
- Prevent damage to vegetable gardens.
- Reduce stress on chickens, which then grow bigger and have more meat.
- Feed chickens extra food so that they grow faster and bigger.

Chicken houses can be part of a chicken yard, an integrated system or just to protect the chickens at night. If you want to have more chickens and improve production, remember that the first four weeks of a chicken's life are the most important!

If you protect and feed the chicks you have:

- Many more chicks that grow into adult chickens.
- Healthier chickens.
- Larger and faster growing chickens.

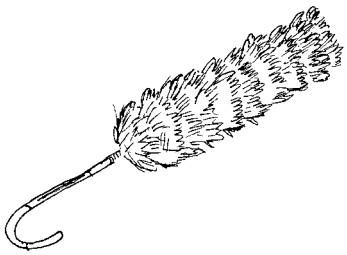
First of all, what do the chickens need and what products do they give?



Cycle of chicken products and needs

CHICKENS' NEEDS	CHICKEN PRODUCTS
Food	Meat
House	Eggs
Water	Manure
Laying box	Feathers
Protection from predators	Income from selling chicken products
Shade	Work – weed and pest control
Medicine	
Dry earth	
Friends – other chickens	
Fresh air	
Crushed shells, crushed eggshells and sand	

Chickens are mainly self-sufficient – they provide most of their own needs – except sometimes they may need medicine and protection from predators. If you make a house for the chickens, you need to provide some of their needs for them.

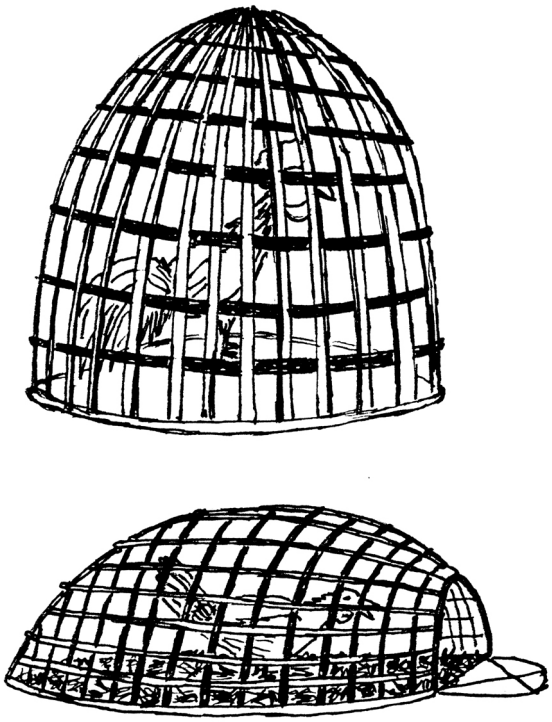


Chicken feather duster

Chickens' needs

NIGHT HOUSE

A chicken house is much easier to manage if it is close to the house and a water supply. Some people just have roosting boxes to protect chickens at night. This is good to keep chickens safe from predators and for collecting eggs, but it is not as easy for collecting manure.

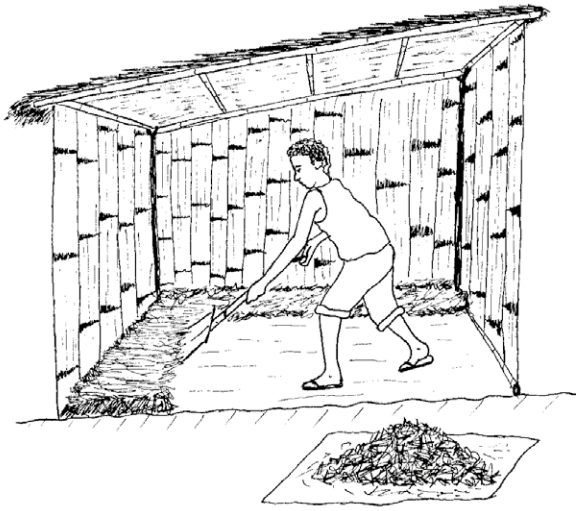


Traditional night time roosting cages

House: A chicken house needs to provide protection from the rain and predators, and places for chickens to roost and to lay eggs. The size and shape, and building materials used depend on what you want and have available. Local materials are cheaper and easier. Train the chickens to come back each night by giving them some rice, grain or crushed corn in their house. Do not let the chickens out until they lay their eggs, usually by mid-morning to midday.

The floor can be cement, which is easier to clean and more hygienic, or dirt. The dirt must stay dry or the chickens might become sick. Add a layer of dried grass on the dirt floor to collect the manure. Remove the grass and manure once every month and use it in composts or liquid composts. It is strong high quality fertiliser, but too strong to put straight onto the garden.

You can use biochar combined with some rock dust (such as dust from granite or basalt) as the bottom layer of animal bedding. It soaks up excess liquid, ties up nutrients, and limits nitrogen loss. ALWAYS add a thick layer of other bedding material on top of it, such as straw, wood chips or sawdust. Read Soil (**Ch 9**).



Cleaning out the house and collecting the material for making compost

Protection: The house must be strong enough to protect chickens from predators and stop other animals, such as pigs and dogs, entering to look for food.

Water: Healthy chickens need a continual supply of fresh water.

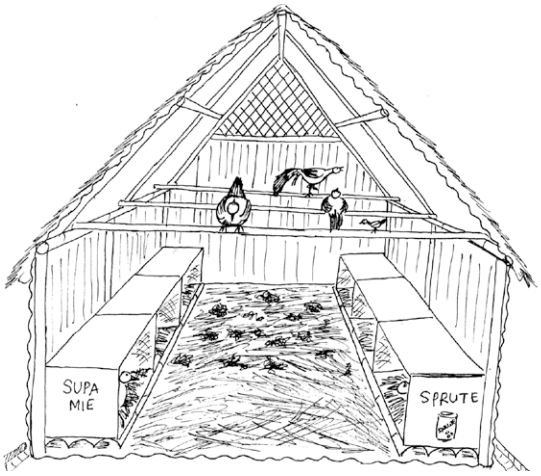
Laying box: Chickens need a comfortable protected place to lay their eggs. This can be a box or a nest made from grass inside the chicken house. Collecting eggs becomes an easy job once the chickens start laying their eggs in one place.

Roosting poles: The house needs some horizontal poles, off the ground, for the chickens to roost on at night.

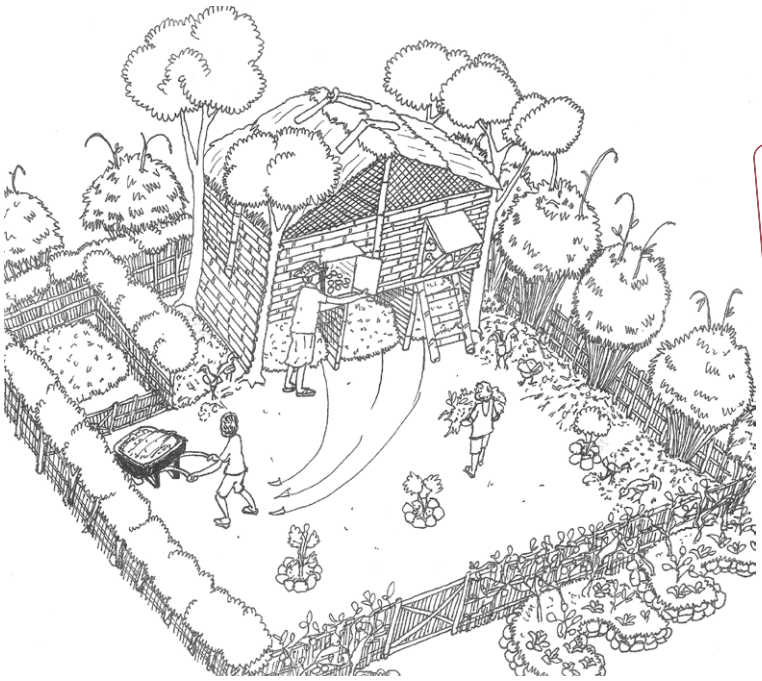
Fresh air: If you make a chicken house, do not keep them inside all day. Make sure that the house allows some wind and air through – no fresh air is bad for their health.

Benefits of chicken houses:

- The chickens are free to wander and eat during the day, and you can still collect eggs and manure.
- Chickens are protected, especially the chicks.



Inside a chicken house



Chicken house on top of compost heaps as part of a permanent chicken house and yard

SMART IDEA:

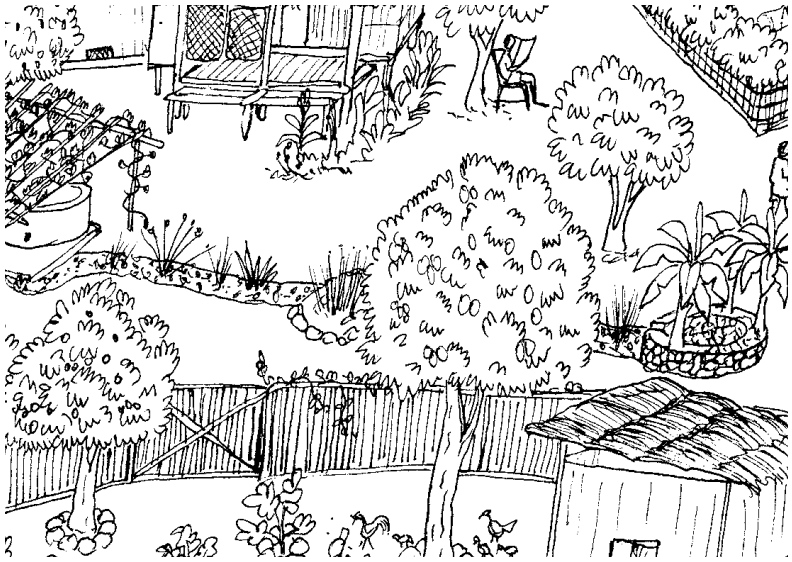
Build compost bays, using living legume trees as poles, and build a small chicken night house above it. With a wire mesh floor the manure falls through straight onto the compost heap, and the legumes provide food for the chickens and the compost!

PERMANENT CHICKEN HOUSE AND YARD

You can build a chicken yard that the chickens never have to leave by providing all their needs. A permanent chicken area – including a house and a place to feed – is better for controlling chickens and provides many more benefits than a night house. First build a night house and, after time, make a permanent chicken area.

Plant trees for fruit and chicken food in and around the chicken yard. Panama berry, mulberries, edible *Syzygium samarangense* species from the myrtle family – such as wax jambu – loquats, mangoes, moringa, sesbania and acacias are good. Bananas and citrus also grow very well in chicken yards but you must protect the roots from scratching.

Prune the lower branches so the chickens cannot climb up and out of the yard. Place rocks or other heavy materials on top of the mulch around the trees to stop the chickens scratching the roots. Bamboo provides shade and wind protection, chicken food, and many other products. Vines are also excellent to grow: e.g. passionfruit, choko, bean, luffa, cucumber and gourd.



Chicken yard with house, living fence, fence with vines, scratching area and productive shade trees

Always have a thick layer of pulled weeds and mulch in your chicken yard. Insects live and breed under them, which provide a constant protein source for the chickens.

A multifunctional chicken yard provides many benefits:

- It stops chickens from damaging your garden
- The trees provide shade and food for chickens and people
- You can continually collect a lot of manure and use it to create excellent soil
- Fruit and vegetables grown in and outside the yard or on the fences benefit from the chicken manure nutrients
- You can throw in weeds and weed seeds for the chickens to eat to help reduce the number of weeds in your garden

FOOD

The chickens must have food each day.

Green leaves and fresh food:

- Kitchen food waste, weeds, rotten fruit and vegetables are all excellent chicken food. **Be careful**: too many tomato and avocado skins can make them sick.
- Outside the fence grow food for the chickens: sweet leaf, amaranth, Brazilian spinach, comfrey (high altitudes), pigeon pea and more. Some of the fence poles can be living trees that also provide chicken food.
- Give seaweed (where available) to chickens once a week to supplement their vitamin and mineral intake. Fish bones (dried and powdered) are also a good source of sodium, calcium and phosphorus.
- Purslane is especially good for chickens, and other animals. It is easy and fast to grow from seeds or cuttings, and can be constantly picked. It is native and common in many tropical countries and grows well in most conditions. A small handful per chicken per day is great because purslane converts the fatty acid in their eggs to omega-three essential acid, which makes the eggs healthier for people to eat.

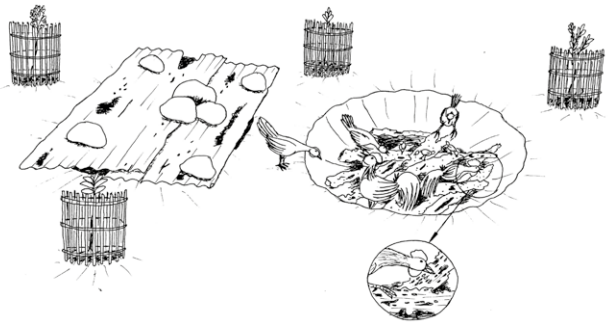
Grains:

- Chickens need some grains as well such as corn, sorghum, rice, etc. Soak the grains and let them grow for a day. The grains then have more nutrients and protein for the chickens. Give approximately a large handful for every ten chickens each day. Grains sometimes cost money but the value is returned in more meat and eggs, so more income, and longer lives for the chickens. Sometimes it is not possible to provide grains, so alternatives include local grass seeds, tree seeds and cooked root vegetables.

Insects for protein:

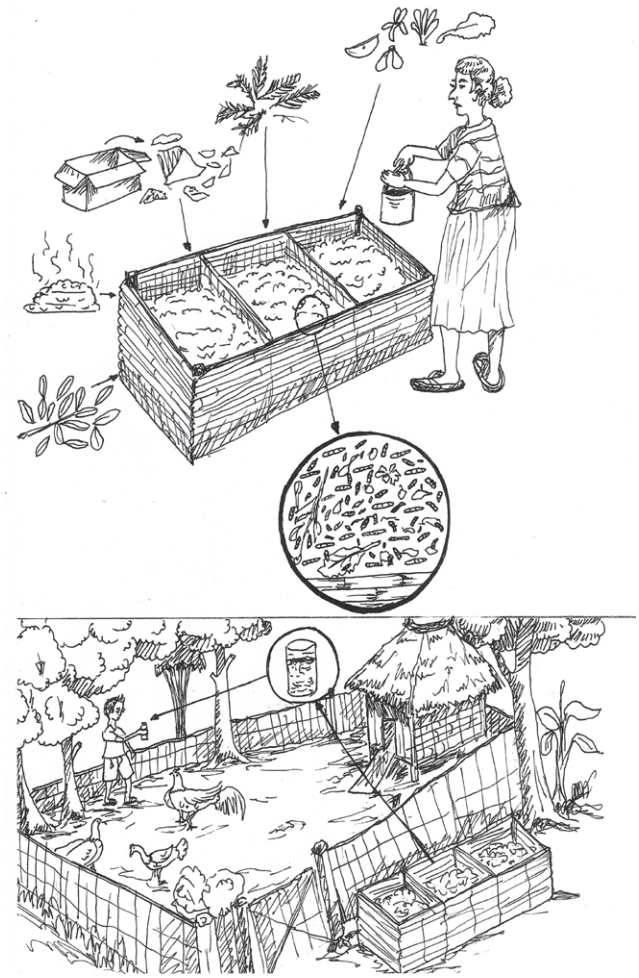
- Most importantly chickens need to be able to scratch for insects and worms. By covering an area with weeds, leaves, rice husks, coffee husks and grasses you provide the insects with somewhere to live. The chickens scratch through it and eat the insects. After one to two months the grass and weeds have lots of chicken manure mixed through. It is high quality compost material, so remove, add to composts and replace it.
- Breed termites for chicken food:
  - Dig a hole in the ground inside the chicken yard.
  - Place rotting wood in the hole.
  - Wet the wood, cover it and leave it for a minimum of two weeks.
  - Uncover it and let the chickens eat all the termites.
  - Repeat the process.

If you have space, this method works even better with two, three or four holes with wood. Open one hole at a time to provide food more often. This method does not need a permanent chicken area. The ground around the holes becomes nutrient rich, and the remains in the holes are excellent fertiliser.



Termite holes producing chicken food

- Breed soldier fly larvae (maggots). They are a common fly that quickly produce larvae up to 2cm long and chickens love them! In containers outside the chicken yard add dry and fresh leaves, weeds, kitchen waste and rotten food. The soldier flies quickly come, lay their eggs and the larvae grow within weeks. When they are big, feed a cup to the chickens every day. If you have a few breeding containers there is a continuous supply of larvae.

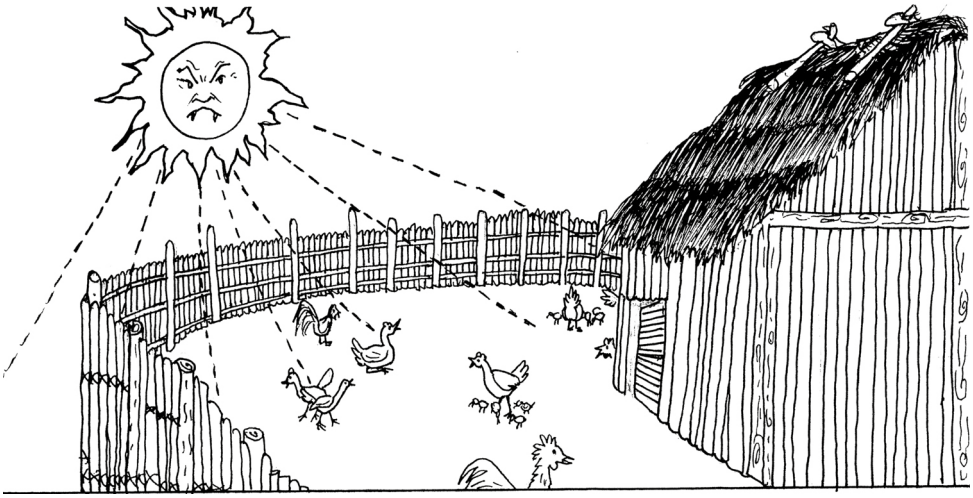


Top: Breeding soldier fly larvae.
Bottom: Feeding soldier fly larvae to chickens

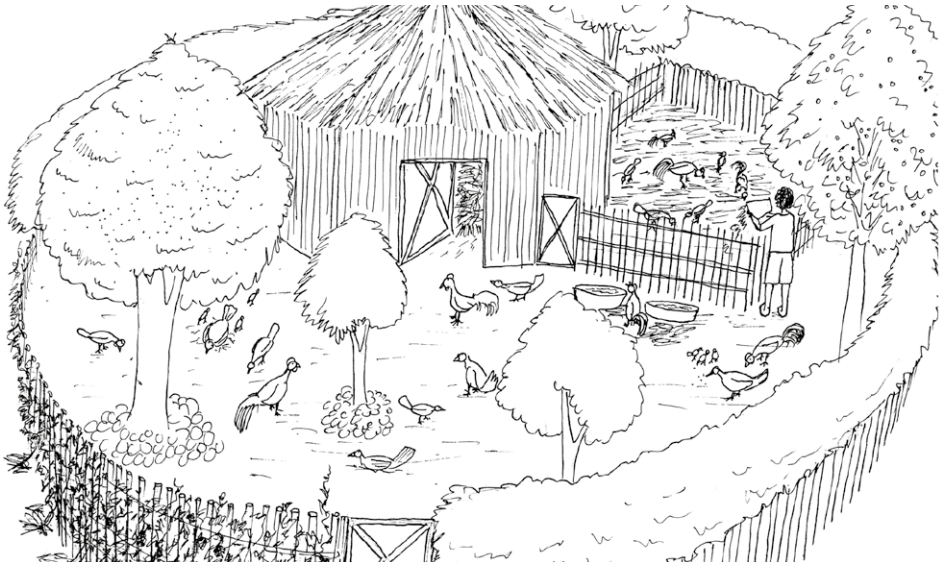
By growing the food you need for your animals, you create a sustainable and low cost system.

SHADE

Chickens' ancestors came from the forest, so they need some shade all day – especially midday – to be healthy. It is essential to plant bananas and at least one or two good shade trees, such as panama berry, mango, or an edible *Syzygium samarangense species* (wax jambu).



No shade



Good shade

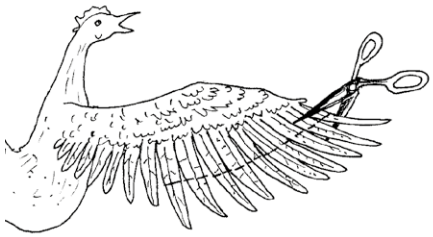
FENCES

Keep the chickens in one area with fences. If you use living fences, they also provide shade, food for chickens and people, space for vines, windbreaks, bamboo or wooden poles and more: use multi-functional solutions. The fence needs to be high enough to stop the chickens from flying away, otherwise make a simple roof using palm leaves or split bamboo.

FRIENDS

Chickens always live in flocks (families). Having too few or too many chickens in a small space is bad for their health. If they live freely, the flock size evolves naturally; one rooster for every 10 to 15 hens works best. If you keep the chickens in a house, you need to manage the flock size for them. When the young chickens develop the males can be separated or eaten.

CLIPPED WINGS



Another way to keep chickens in a fenced area is to clip (cut) the feathers on one wing.

Method: Cut in half the long outside feathers on one wing. Also cut in half the smaller feathers on the outside of the wing under the main large feather. This upsets the chicken's balance and prevents flight. This works for three months for young chickens, and for up to a year for older chickens.

HEALTH

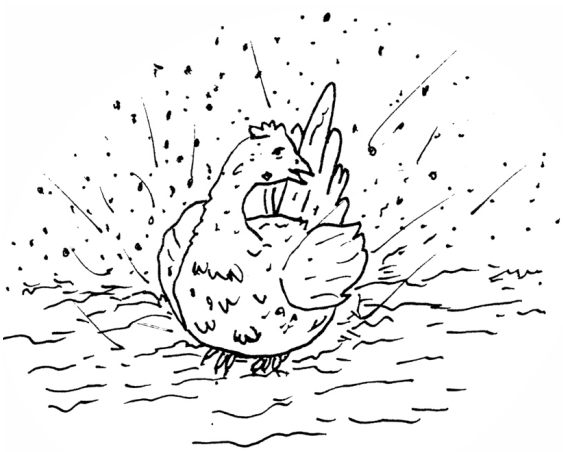
Prevent disease: Chickens are generally healthy animals which care for themselves. You can help prevent disease by keeping the chicken house dry and cleaning it regularly. Providing good feed is also an important prevention measure.

Providing chickens with crushed eggshells and seashells, and sand is necessary. They naturally eat small amounts of these with their food. It helps their digestion and ensures they produce eggs with strong shells.
Be careful: if you do not dry and crush the eggshells, the chickens might start eating their eggs.

Chickens also like eating chillies and garlic, which help them to fight off minor sicknesses. Occasionally add small amounts of each to their food.

Separating sick chickens: If your chickens do get sick, separate them from the healthy chickens until they recover to stop the disease from spreading. If your chickens mix with other chickens in the community, there is more chance of diseases spreading.

Lice and mites: Chickens dig holes in dry earth and shake the dirt through their feathers to remove lice. This is **very** important for good health and, if chickens are free to range, they find dry earth themselves. If they are in a yard you must provide it for them in the wet season.



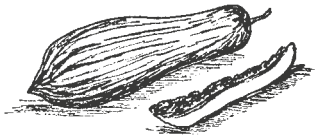
You can add some wood ash to their dry earth holes, and add some neem, bamboo or duranta leaves (a common hedge plant with yellow berries) to the chicken yard regularly. They have a natural pesticide that does not negatively affect animal health and helps to reduce lice and mites. Wormwood grows in dry tropical climates; a plant in the chicken yard is a natural mite repellant.

Natural antibiotics: There are many tree leaves that provide natural antibiotic protection for chickens; they are free, organic and produce better results than pharmaceutical antibiotics. Guava (*Psidium spp*), jambo (*Syzygium cumini*), tamarind (*Tamarindus indica*) and *Eucalyptus* spp are good examples.

Collect the young leaves, and wash and cut them into small pieces. Boil them in water for ten minutes – a large spoon of chopped leaves for three to four cups of water. Cool and bottle the liquid to use as drinking water for the chickens once every two weeks to one month to prevent illness, or when they are looking sick.

Vaccination: Two viruses – Newcastle disease (very infectious and begins with breathing problems) and Marek's disease (fowl paralysis which attacks young birds in particular) – kill lots of chickens in many countries. They spread very quickly and occur every year, usually at the end of the dry season. The most effective control is vaccination. The chicken should receive the vaccination when it is young, and all the chickens in a community must be vaccinated for it to be effective. Government agricultural departments and some NGOs run vaccination programs. Contact government agricultural workers for more information.

Treating worms: A good natural worm treatment is papaya seeds. Chickens like eating them, especially seeds from green papaya. Feed them the seeds regularly to help prevent problems. Add neem powder regularly to the yard, or add to their food, to reduce worms and other stomach sicknesses. Mix a large spoon of dried and crushed mulberry leaves to food or water occasionally to help prevent worms and as a general preventative treatment. Add crushed garlic to the chickens' water if they have worms – the most common types are roundworms, gapeworms and tapeworms – or if they are quiet and their combs have drooped.



Preventing worms: It is much better to prevent worms in the first place. One method is to make sure chickens always have some clean ground to scratch around, reducing the chance for worm larvae to multiply.

Aloe vera leaves Aloe vera can be used in many ways. The insides of the leaves are very healthy and you can give them to chickens as a food supplement. If the chickens do not like eating the leaves, mix the gel from a small leaf into their drinking water once a month. The aloe vera gel can also be used on cuts to help prevent infection and on leg-scale problems.

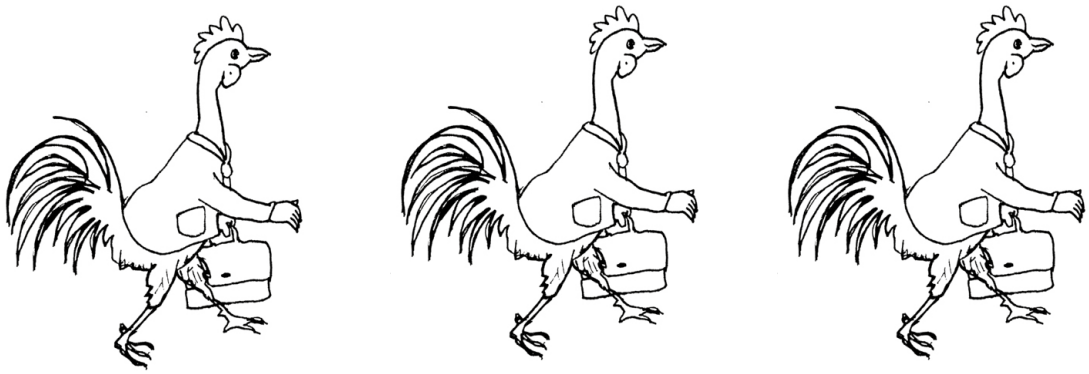
A traditional medicine for coccidiosis – a microscopic parasite that infects the gut – and other diseases is to crush aloe vera leaves and add one small spoon of juice to one litre of water. Use this as their drinking water until they are cured. However, the treatment cannot be guaranteed as more research is needed; it is worth trying if no other treatments are available.

There are many other traditional cures, so learn and share local knowledge.

Chicken products

Chickens provide meat, eggs, manure, soup stock and feathers. The healthier the chickens are, the more they provide, especially eggs. Building a house with a permanent yard enables you to obtain the most chicken products.

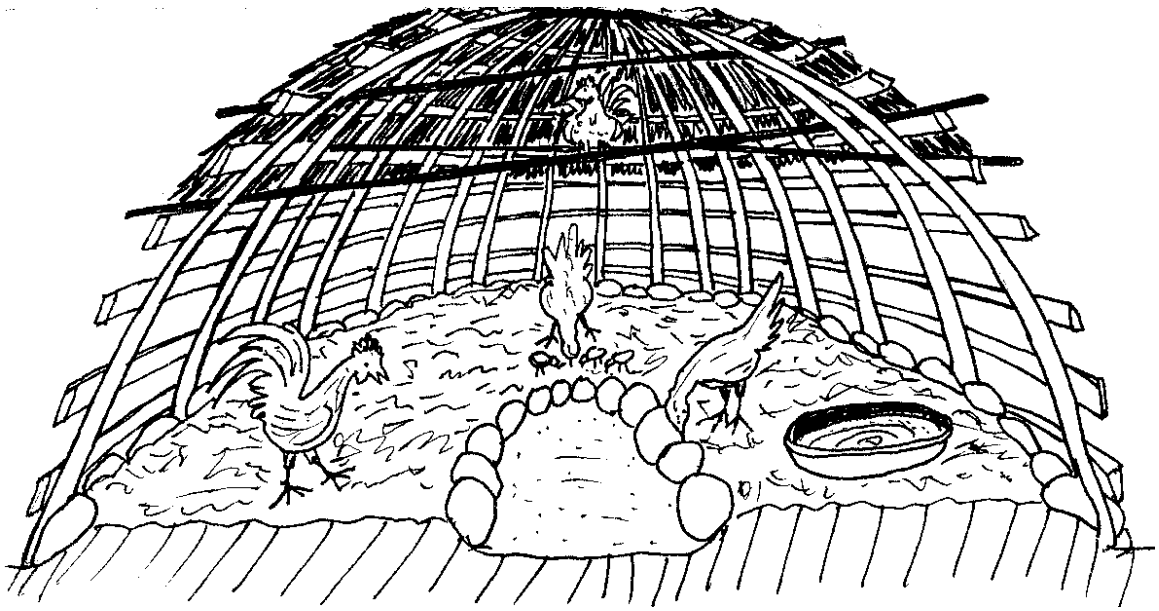
CHICKEN WORKERS



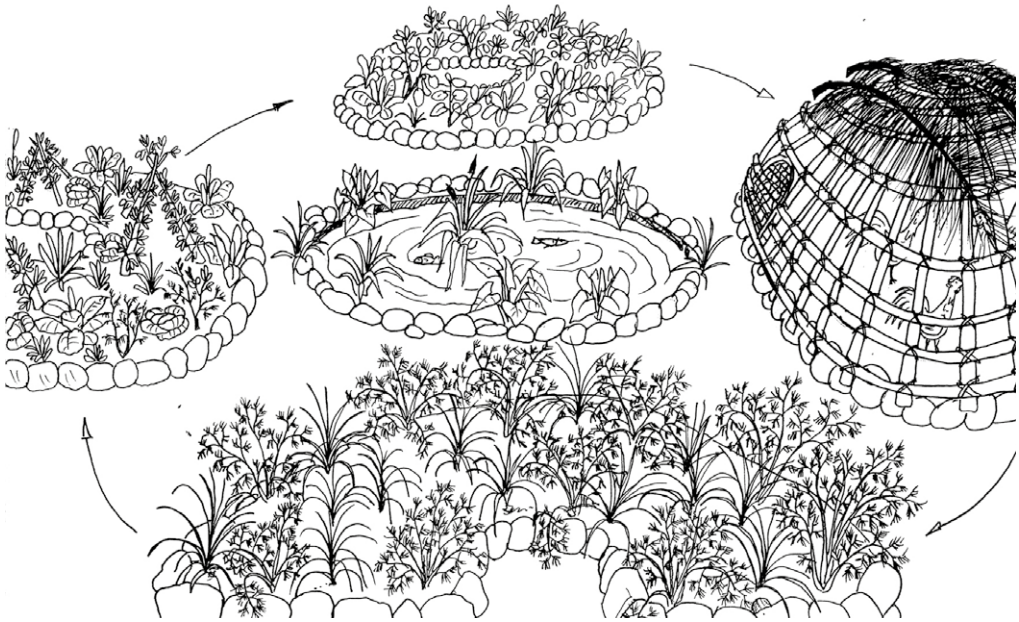
In a well-designed and integrated system chickens fertilise the land and provide pest and weed control. It is called chicken work and they love doing it!

Moveable chicken houses

The chicken house can be moved from one garden plot to another. A good system is to have between three and six different plots all the same size and move the chicken house from plot to plot once every two to three months.



Cross section of movable chicken house



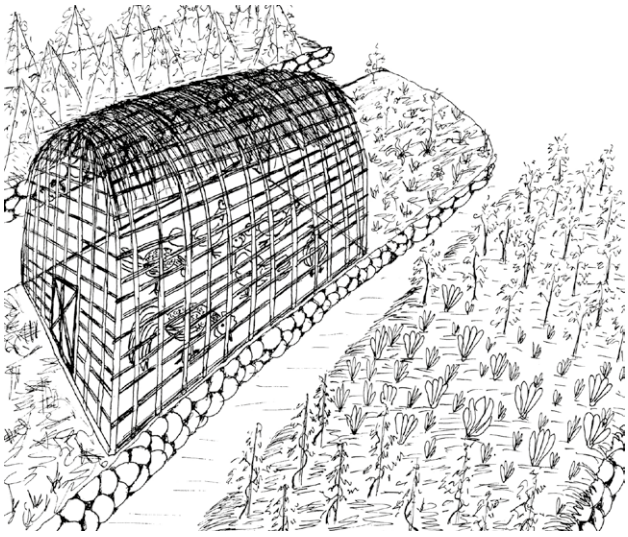
Chicken tractors

A chicken tractor is a small moveable chicken cage with no bottom to put the chickens in during the day. A good method is to have six chickens in a cage 2m x 1m.

A chicken tractor is used to:

- Scratch up and fertilise soil before planting.
- Remove pests and insects from the soil.
- Remove weeds.

The movable chicken house and chicken tractor are good for keeping hens and baby chicks. Try to build it as light as possible – treated bamboo is good material – to make it easier to move.



SMART IDEA:

Do not feed chickens while they are in the tractor or they will not work for their food!

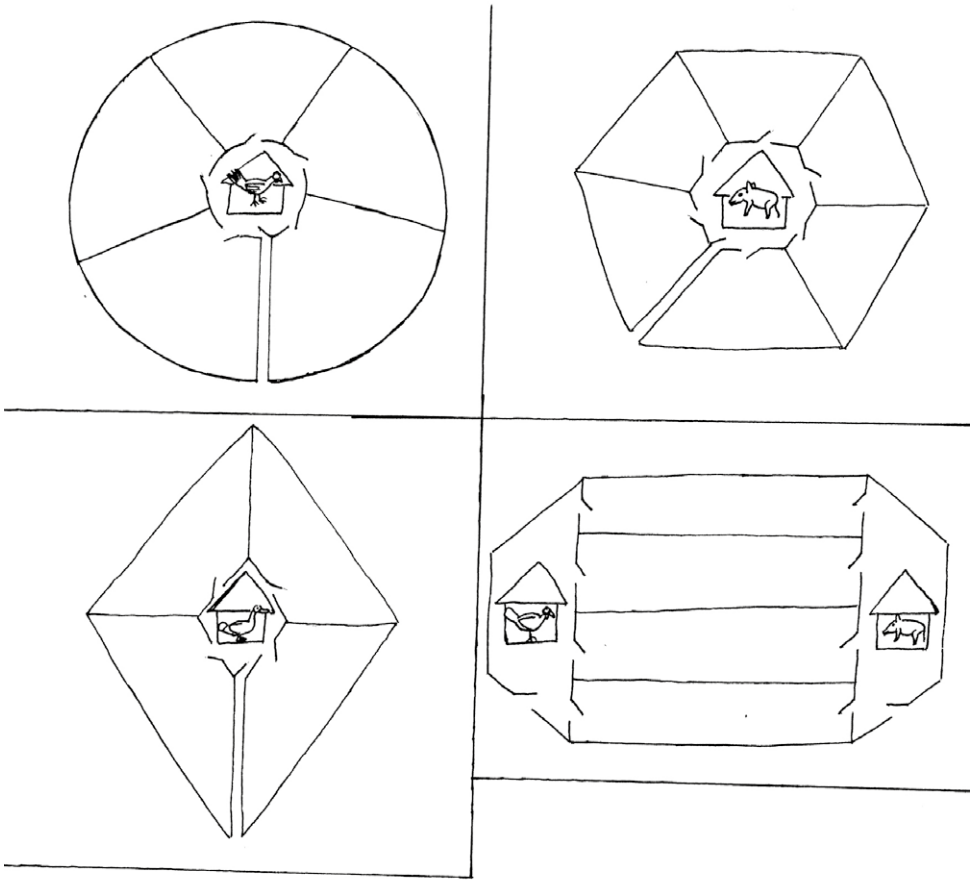
Chicken systems

CHICKEN AND VEGETABLE SYSTEMS

Chickens can help in the vegetable garden.

Divide the garden into sections of approximately 5m x 5m, but they can vary in size. Each section must have a tall fence around it or a temporary roof made from palm leaves to stop the chickens escaping. Otherwise you can clip a wing on each chicken.

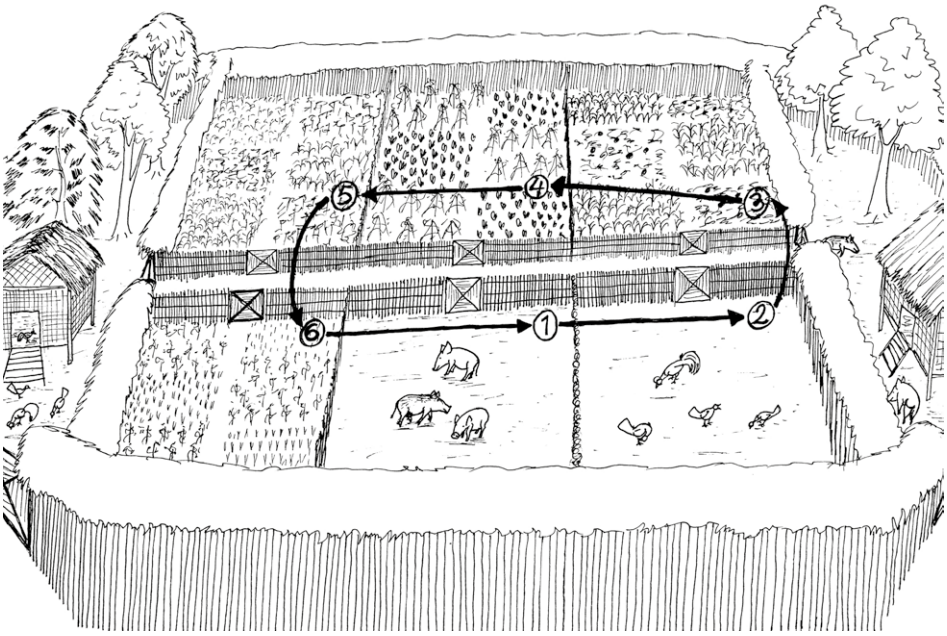
Let the chickens into one section and grow vegetables in the other sections. When a crop is finished let the chicken eat the stalks, weeds and insects. As you provide food for the animals, they are working for you, cleaning and fertilising the area for the next crop and providing important pest control. Move the chickens from one area to another, as you need them. Keep the chickens in a chicken house at night.



Different designs for chicken and vegetable systems

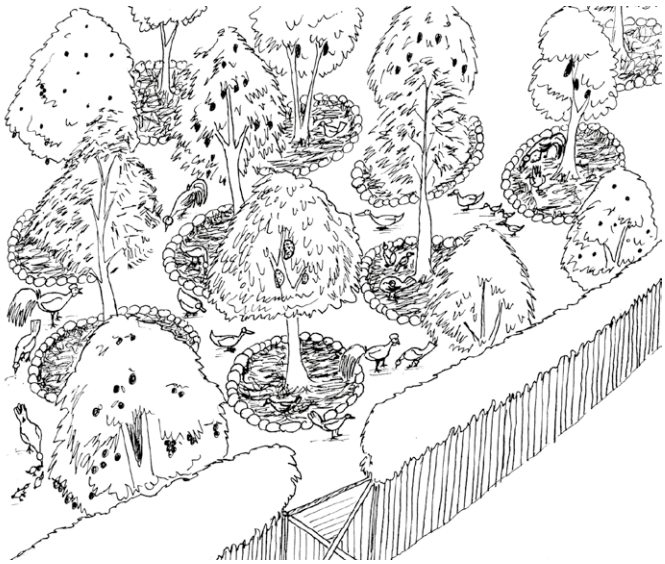
Combining pigs with chickens works even better. Use the pigs first; for a 5m x 5m area two or three pigs is good. Add a layer of dry grass. The pigs dig up the ground, eat out the weeds and turn the dry grass into the soil. Follow with the chickens to scratch around and eat the insect pests and weed seeds. Both add manure to the soil. Allow one or two months for each animal in the section.

If there is no shade, provide a small amount using bamboo poles and palm leaves.



Please note: the arrows point to which number comes next, not to the direction of the rotation

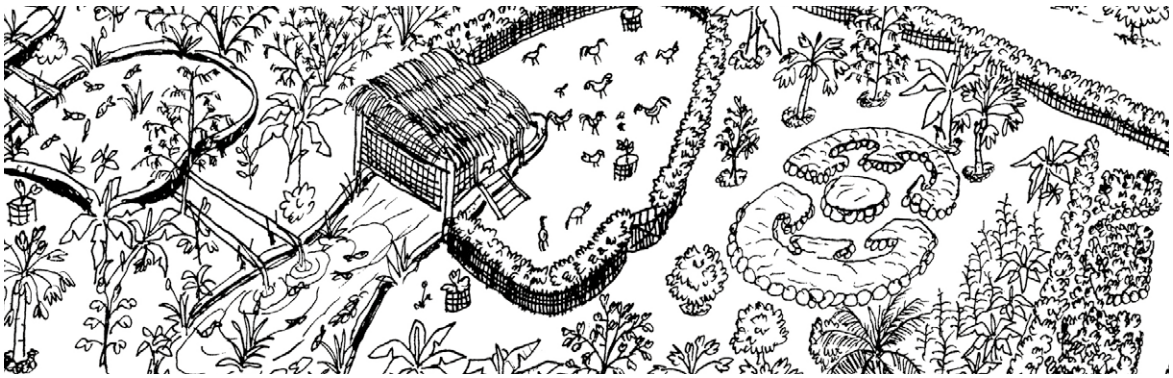
CHICKENS AND FRUIT TREES



Chickens are excellent for managing the ground around fruit trees. About 50 chickens for an area 50m x 50m can eat the weeds and fertilise the trees. Make sure that the fruit trees are at least a year old before introducing the chickens. Make a stone ring around each tree, 1m–2m from the trunk, and place lots of compost and mulch inside the ring. The chickens can scratch around but the stones keep the compost and mulch near the trees. Otherwise make a 40cm high fence with wire instead of the rocks.

Plant legume trees to make a living fence and in between the fruit trees too. Cut the legume trees to feed to the chickens and provide nitrogen to the fruit trees.

Chickens and fish systems is another good combination: read more in the Aquaculture chapter (**Ch 18**).



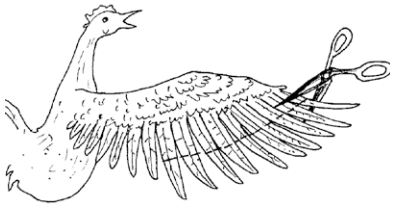
Community chicken management

Chickens can be a big problem in family gardens if they are left free. However, sometimes it is the neighbours' chickens that are the problem!

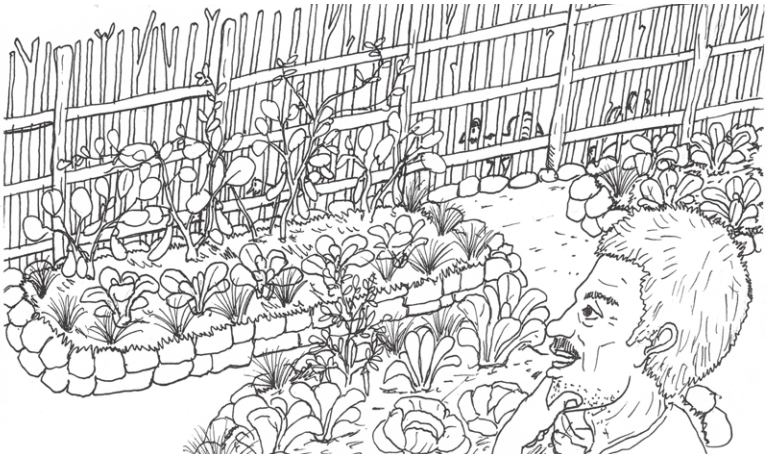
Solutions need to include community understanding about chicken management. This could be a community agreement including how to prevent damage from wild chickens and what penalties there are for destroying garden beds. The best solutions for this problem are already explained above: houses, permanent yards and clipped wings.

1. Chickens destroy Gibrael's vegetable garden

2. A community is held to find a solution

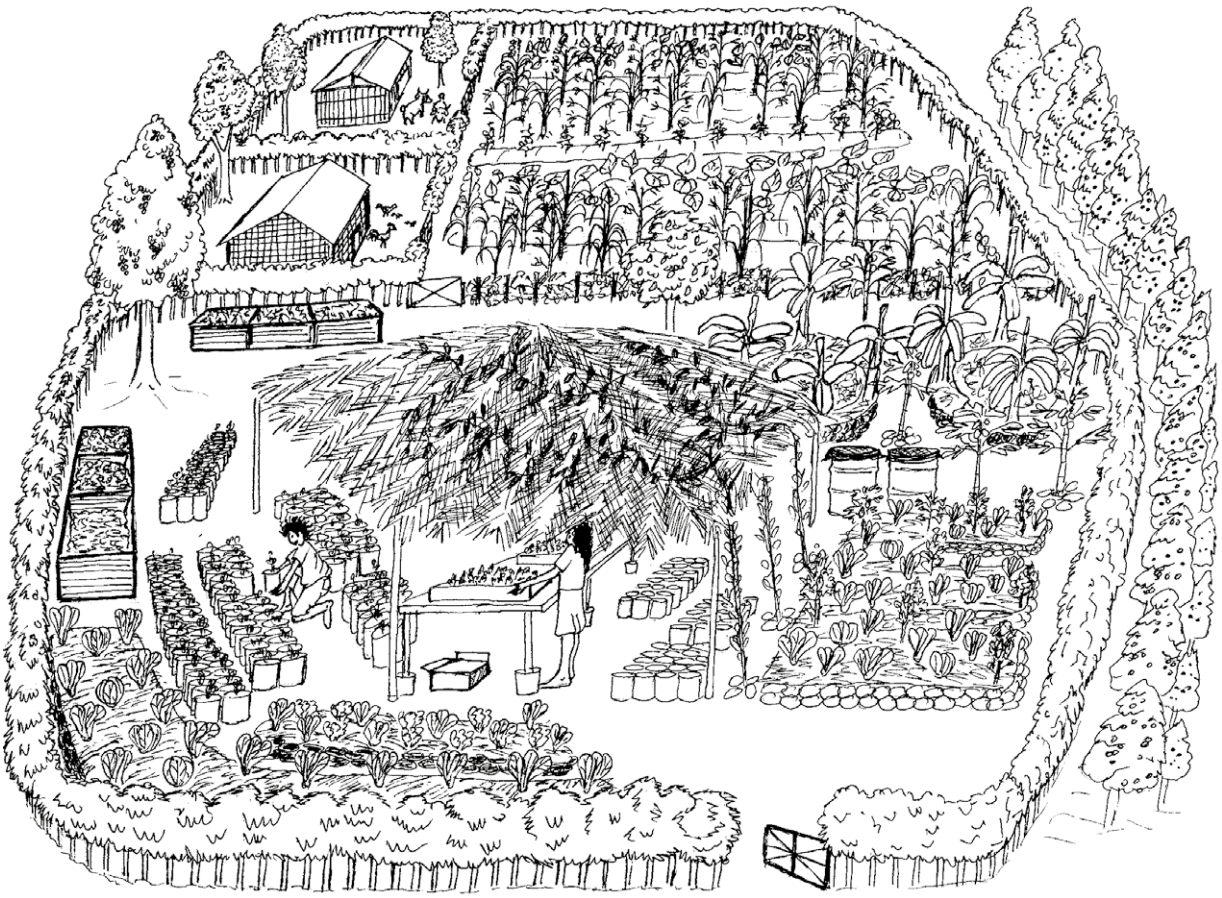


3. The chickens get their wings clipped



4. Gibrael is happy that his vegetable garden is protected and growing well

Another idea is to protect your garden beds using stones, wood, branches with spikes, upright sticks in the soil and other things that prevent chickens from scratching.



Chickens are managed as part of a animal and crop rotation system

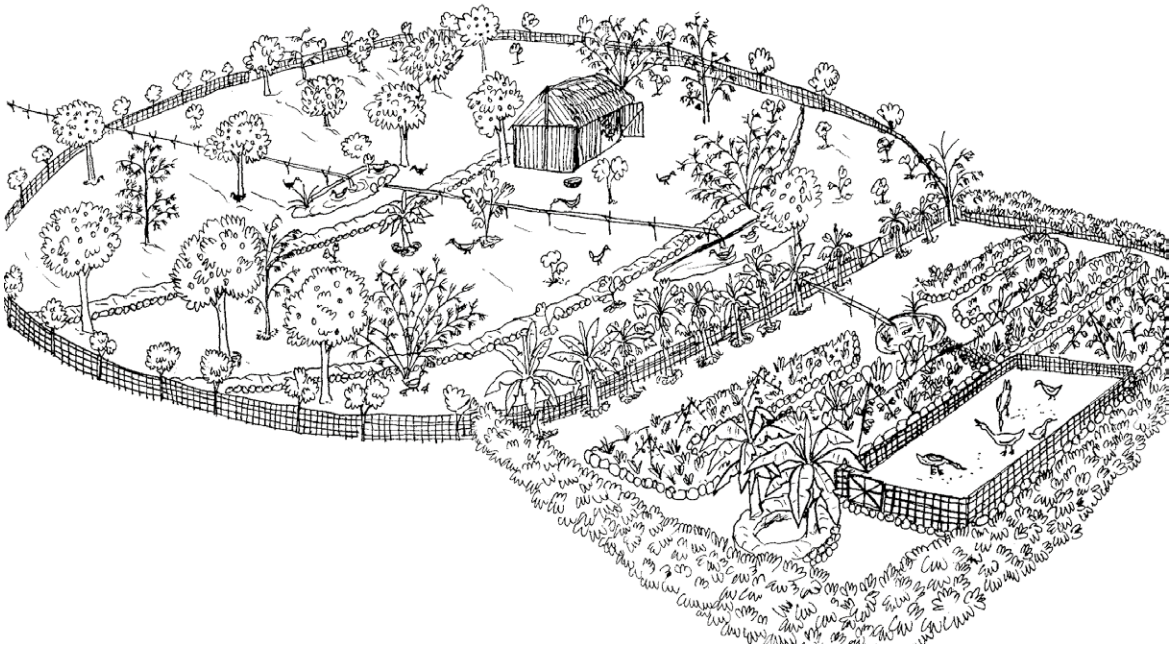
SMART IDEA:

Choose from the techniques you like best, combine different techniques or try your own.

Ducks

Ducks are easy to breed and provide many different products for an income. They do not often get sick and do not suffer from Newcastle disease (though they may be disease carriers), which kills many chickens each year. They can be easily integrated with agriculture such as rice and vegetable production, and fruit trees. Ducks need food, water, shade and shelter to be healthy and happy.

The first four weeks of a duck's life are the most important. If they have good food and water in these weeks it helps them to grow faster and bigger, and they get sick less often. This is also when they are most likely to be killed by predators. A little bit more work during this time results in a lot more benefits later on.



An integrated duck system

DUCKS' NEEDS	DUCK PRODUCTS
Water	Meat
Food	Eggs
House	Feathers
Shade	Manure
Protection from predators	Income from selling duck products
Medicine	Labour – weed and insect control

Ducks' needs

WATER

Ducks need a continuous supply of water, a container or small hole filled with water that they can drink from while they eat. Ducks need the water to help swallow and digest their food. Ducks also like a pond or other water to swim in and look for food. This is not essential, but it is good for their health and is an excellent source of liquid fertiliser. Ducks can also be combined with water plants if the pond is big enough.

FOOD

Duck food

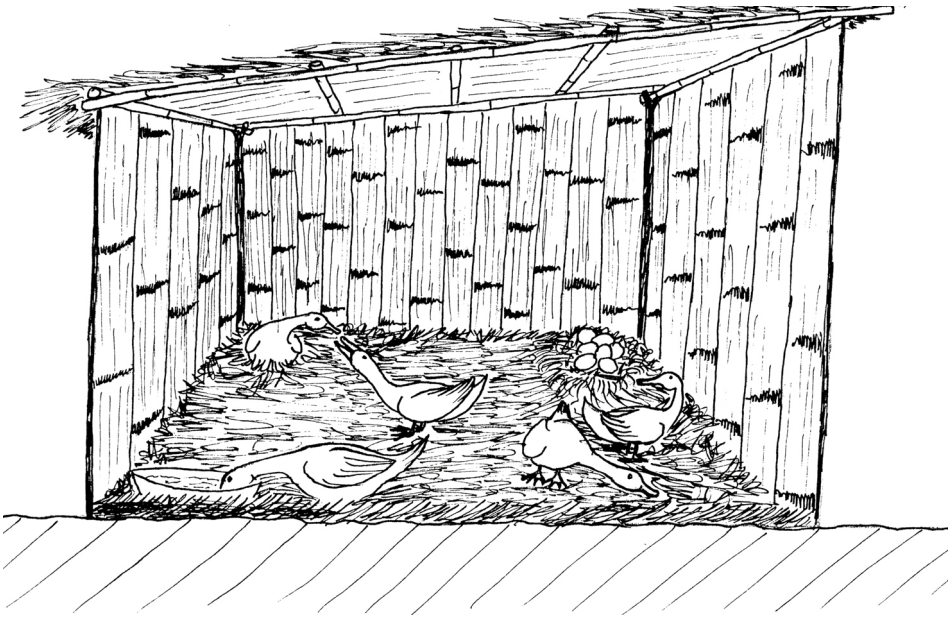
Ducks like a mix of insects, worms, fresh grass and leaves, and grains (rice, corn, millet).

- They hunt for insects and worms in the soil, on the edges of ponds and under mulch and leaves. It is much easier for them to find insects and worms if the soil is wet.
- Ducks like grass and leaves if they eat directly from plants or they have just been picked. Be careful because they love vegetable seedlings! Outside the fence grow sweet leaf, amaranth, Brazilian spinach, comfrey (high altitudes), pigeon pea and more. Some of the house or fence poles can be living trees that also provide duck food.
- Give seaweed, where available, to ducks once a week to supplement their vitamin and mineral intake. Fish bones (dried and powdered) are also a good source of sodium, calcium and phosphorus.
- Purslane is especially good for ducks. (Read above in the chicken food section for how to grow it.) A small handful per duck per day is great because purslane converts the fatty acid in their eggs to omega-three essential acid, which makes them even more healthier to eat.
- Ducks need some grains as well, such as corn, sorghum, rice, etc. See the chicken section for how to feed grain to ducks.
- Breed soldier fly larvae (maggots). Ducks love them as do chickens, so see the chicken section for more information and illustrations.

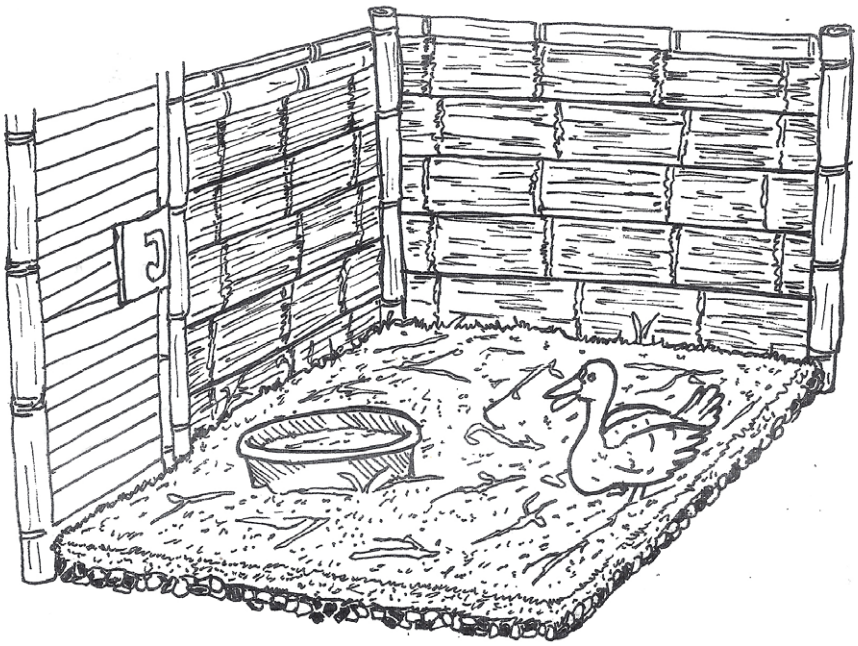
DUCK HOUSES

Ducks cannot roost in trees like chickens, so they need a house. This provides a place for them to lay eggs and protection at night from dogs, cats, snakes and rats, especially for ducklings. A duck house can be as big or small as you need it. 2m x 2m is a good size for 10 to 15 ducks; 3m x 3m for more ducks.

Always provide a thick layer of cut grass on the floor for the ducks to make nests for their eggs. Replace the grass every one or two months when it is full of duck manure. This is excellent compost and fertiliser, but be careful how you use it because it is too strong to put directly onto garden beds. Remember to put a water container inside the house.



You can use biochar combined with some rock dust (such as dust from granite or basalt) as the bottom layer of animal bedding. It soaks up excess liquid, ties up nutrients, and limits nitrogen loss. **always** add a thick layer of other bedding material on top of it, such as straw, wood chips or sawdust. Read Soil (**Ch 9**).



Biochar and rock dust under duck house bedding

SHADE

Ducks need some shade, especially in the middle of the day. Trees or a simple shade structure with palm leaves works well.

HEALTH

Ducks do not often get sick if they are well cared for. You can prevent most problems by providing food and clean water for them to drink every day, and cleaning their house regularly.

Add some papaya seeds from green papayas to their food regularly to reduce problems with worms. Garlic can also help, so crush it and add to their water or food.

Read the chicken health section for further measures that can also help for ducks, such as natural antibiotic medicines, and aloe vera for cuts and leg-scale problems.

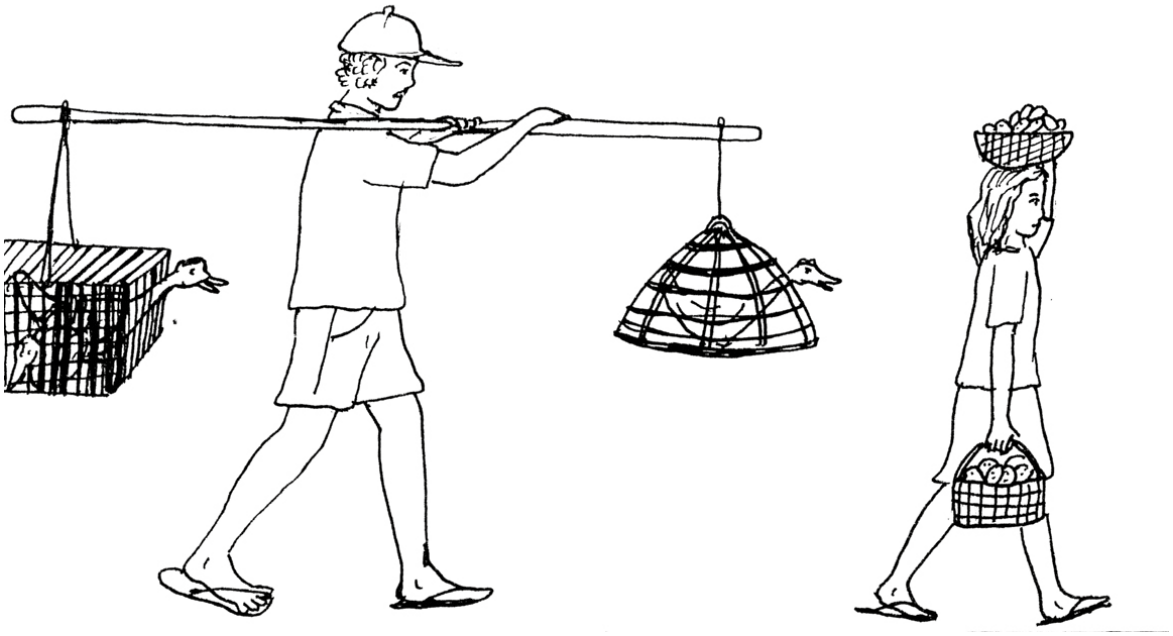
Separate the sick from the healthy ducks to stop disease from spreading.

Duck products

Duck meat is a very tasty delicacy in many countries. Duck eggs are twice as big as chicken eggs and are healthy and tasty to eat. Both the eggs and meat can be traded or sold.

Duck manure is excellent fertiliser but it is strong. The grass/manure collected from the duck house needs to be mixed into compost or liquid fertiliser before use.

Ducks can be combined with rice and fruit trees and can be used for pest and weed control. The following examples give some details.



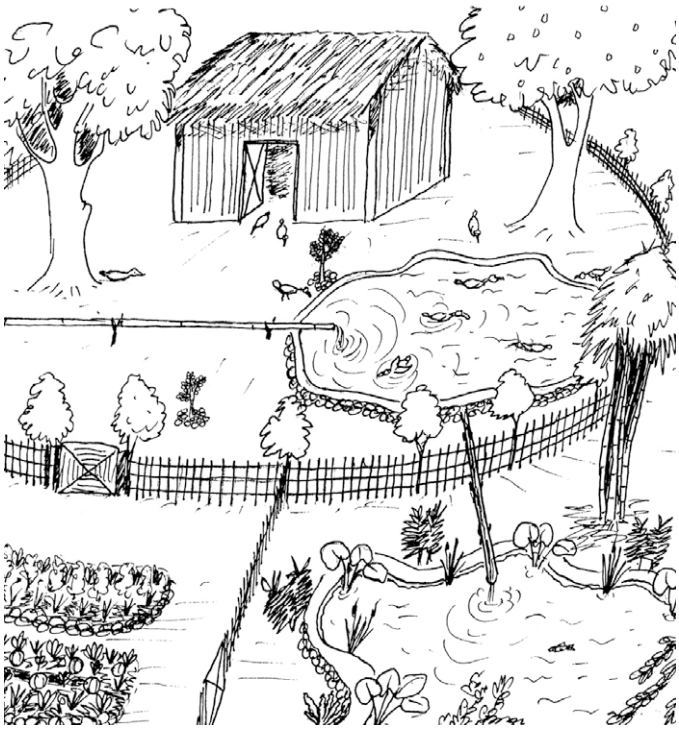
Duck systems

Ducks need checking on and must have water every day so place the duck house close to daily activities and a water supply too.

NIGHT HOUSES

Ducks need a house at night but they can freely roam during the day. This system is very low maintenance, but you need to protect vegetable gardens from them. Ducks love seedlings and green leafy vegetables; they eat a lot very quickly!

DUCK HOUSES WITH FRUIT TREE YARDS



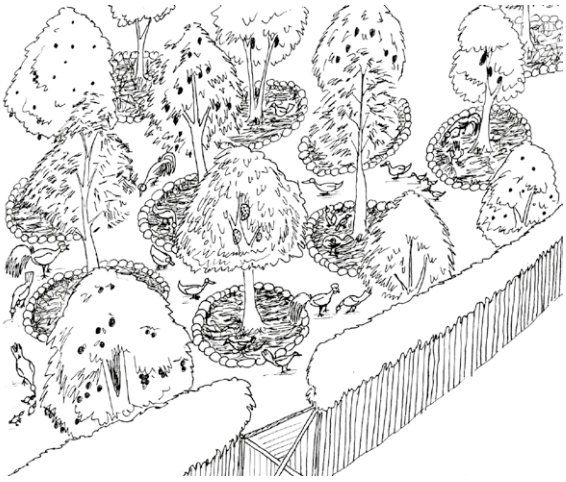
An area for ducks is much easier to build and maintain than a chicken yard. The fence only needs to be small because the ducks do not jump fences or fly as high as chickens. A living fence of legumes and other plants provides duck food and other benefits.

The ducks control the growth of grass and weeds around the fruit trees, eat some pest insects and fertilise the trees at the same time. Ducks like to sit in the shade, and defecate where they sit, so they fertilise the fruit trees well! Citrus trees and ducks are a great combination because citrus trees like the strong manure and the ducks do not dig up or disturb their shallow roots.

Add a steady supply of weeds, husks, leaves and cut grass to cover the yard for insects to live under, providing food for the ducks. It also helps to absorb some of the duck manure.

DUCKS AND ORCHARDS

While there are similarities, ducks are easier to manage in orchards than chickens and can be used for larger areas. Ducks provide weed and some insect control, and fertiliser. They do not scratch like chickens so are less damaging to tree roots. They work well with chickens but their houses **must** be kept separate. Ducks need a wet house area while the chickens' needs to be dry. If the chicken house area is wet the chickens can become sick.

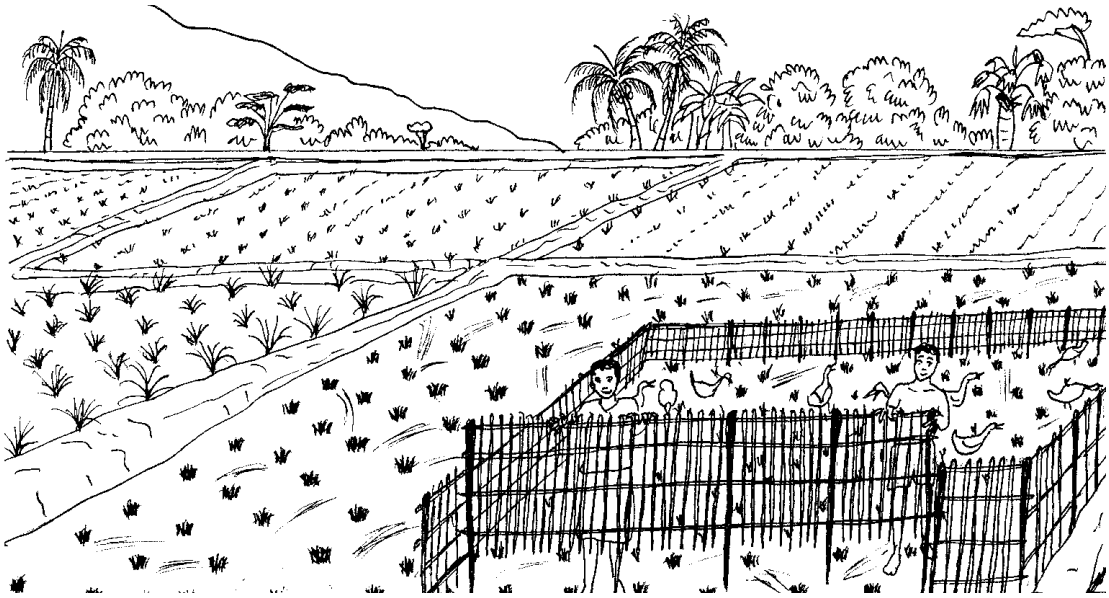


SMART IDEA:

Plant some fast growing legume trees between the fruit trees, especially if the fruit trees are newly planted. The legume trees quickly provide shade and wind protection and can be pruned to provide nitrogen, mulch and duck food.

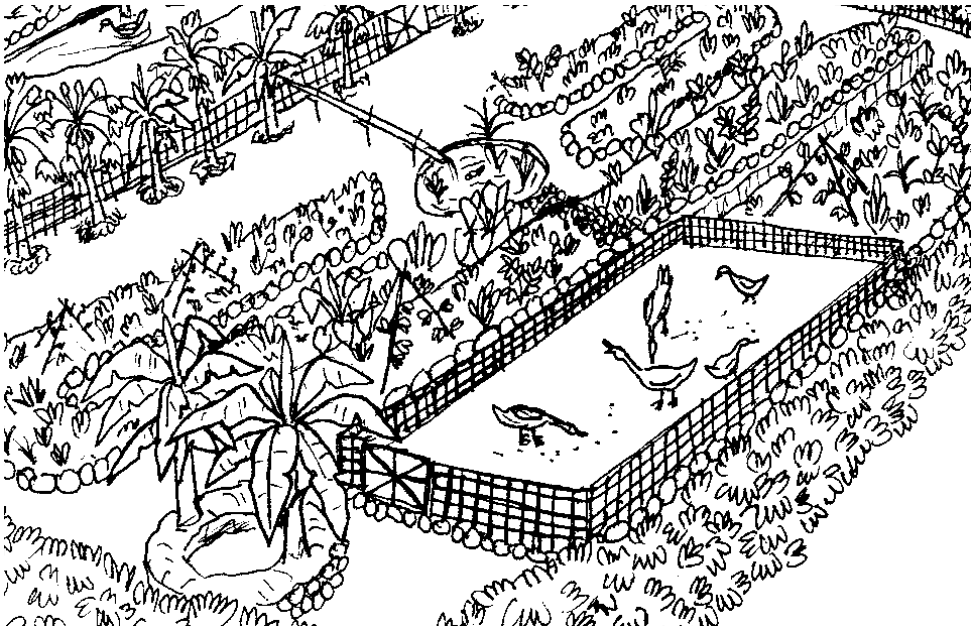
DUCKS AND RICE PADDIES

Ducks eat weeds and fertilise rice paddies after the harvest. Make a small moveable fence to keep them where you want. It is best to move them back to a duck house each night to protect them from predators and collect the eggs.



DUCKS AND VEGETABLE GARDENS

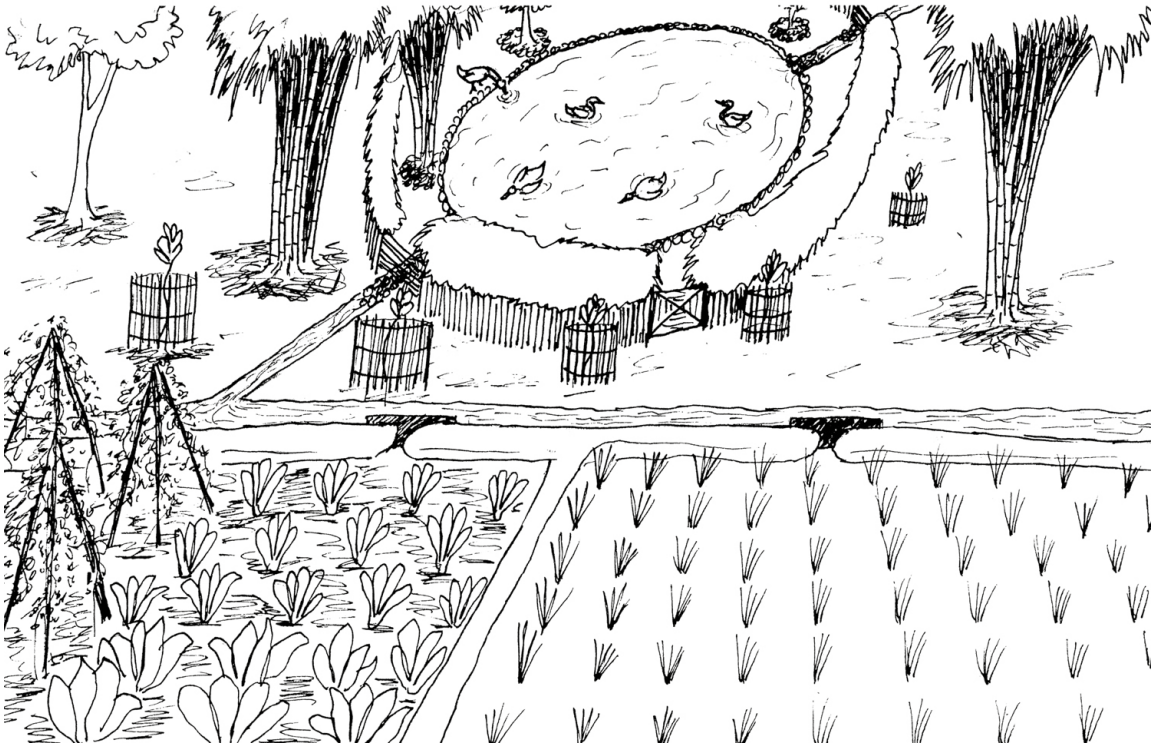
A moveable fence can also contain ducks in a vegetable growing area. This is a good way to combine vegetables and ducks. By using a fence to keep the ducks in one place, they eat weeds and insects, and fertilise the soil before the next crop but without damaging the vegetables.



Important: Provide some shade from the hot midday sun. Look in the Aquaculture chapter (Ch 18) for combining ducks and fish production.

DUCKS AND IRRIGATION WATER

A duck pond is a continual source of liquid fertiliser. It can be combined with irrigation to provide nutrients in the water for the plants. In the wet season especially there is water run-off from a duck pond. You can make swales, paddies or other water catchments below the pond to catch and store the water. It is nutrient-rich water to feed your vegetables, crops and trees.



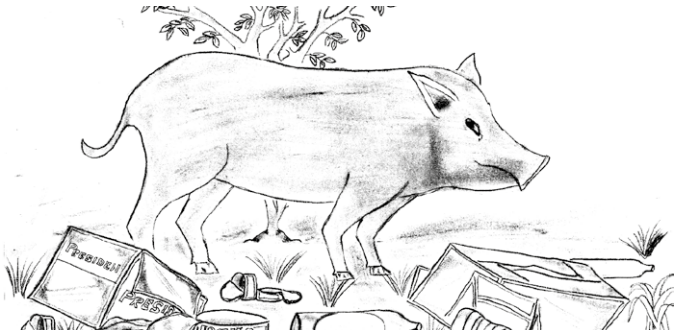
SMART IDEAS:

- Do not use waste water from the kitchen and bathroom for duck water. It contains soaps and detergents, and it makes them sick.
- A duck pond creates excellent liquid manure. Ducks use the pond for drinking, swimming and food. After one to two months a lot of manure accumulates in the water, so mix it 1:10 (1 litre duck water to 10 litres water) for fruit trees, crops and vegetables.

Pigs

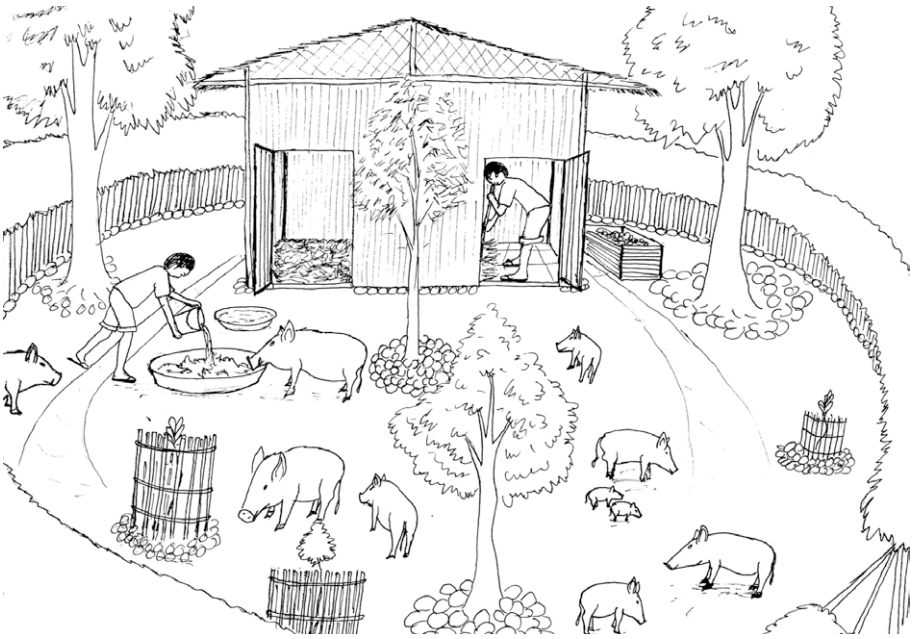
Pig meat and oil are important sources of income, and in some countries they are used in traditional ceremonies. In some cultures people do not raise or eat pigs. Permaculture is about designing systems that suit people's cultures, so whether pigs are part of your farm or not is for you and your community to decide; all decisions should be respected.

People often allow pigs to roam freely, which requires little maintenance and is cheap. However, these pigs get sick easily from bad food, diseases spread quickly, more young pigs die, and there is more chance of your pigs being stolen. Most importantly, pigs cause a lot of damage to crops and young trees if they are not kept in a yard.



Unhealthy pig looking through rubbish

A simple pig house and yard improves pig health and productivity, and protects your crops and trees. You can also collect and use the pig manure, and the pigs can be used for labour.



The practice of pigs eating human excrement is common in some countries, but it is very unhealthy. The pigs can contract diseases from eating the excrement and these diseases can be passed on to humans who eat the pigs. A simple solution is to make a composting toilet that the pigs cannot enter. Look in the Houses, water and energy chapter (**Ch 7**) for how to make and use them.

PIGS' NEEDS	PIG PRODUCTS
Food	Meat
Shelter/house	Leather
Water	Manure for composts or a biogas ingredient
Fences	Oil
Medicine	Labour – weed control
Earth to dig	Labour – land clearing
Shade	Ceremonial needs
	Income from selling pig products

Simple needs

SIMPLE PIG HOUSES

You can start with a simple system and slowly develop it over time.

The pig house – a good size is 3m x 3m – is for the pigs to stay in at night. Small pig houses where the pigs cannot move are not good, as they are smart animals and need to be able to move around. The pig house must give shade and protection from rain and strong winds. If the pig house has no walls, a strong fence is necessary. A cement floor with a gentle slope down to a drain is best to clean for good hygiene and health. Cover the cement with cut grass and change it at least every week. The drain allows you to wash the floor and collect the manure in a bucket. Add this to your compost. Pigs need food and water everyday so it is easier if they are close to the house.

Use the grass and manure as fertiliser and mulch, but it must be composted first. The pig house floor can also be made from wood or split bamboo. It must be raised off the ground and have thin cracks so that it can be cleaned out and does not rot.

Plant some fruit or other trees for pig food next to the pig house to improve the pigs' living environment. Happy pigs are healthier and grow faster and larger. The trees benefit from the pig manure.

During the day let the pigs out to feed or tie them to a stake. If they roam make sure the vegetable gardens have fences. If the pigs are tied to a stake, use the pigs to clear and fertilise land that you use for crops.

FOOD AND WATER

The pigs must have water and food each day: A mix of leaves and roots makes good pig food. Some examples are sweet potato, cassava, yam, taro, canna (arrowroot), sesbania, leuceana, pigeon pea, papaya leaves and fruit and moringa. The cassava must be cooked; the other root vegetables and leaves can be raw or cooked. If the vegetables are old or partly rotten it is better to cook them. Take leaves from other local trees to feed to pigs, too. Powdered rice and corn are also excellent pig food, as is food waste from the kitchen. Beans provide important protein, which improves growth.

To fatten up a pig quickly you can feed them pumpkins, canna, chokos and bananas, especially if it is market waste. Bamboo shoots and banana stalks are also good pig food.

To supplement their vitamin and mineral intake, give pigs seaweed once a week, where available. Fish bones (dried and powdered) are also a good source of sodium, calcium and phosphorus.

HEALTH

Keeping the pig house clean and dry, and giving them enough food and water, ensures the pigs are healthy and prevents most sickness. Add papaya leaves and green papaya seeds to the pig food regularly to treat worm problems. If you give these regularly, about once a month, they prevent other sickness too. Add one or two small handfuls of green papaya seeds and/or one or two big handfuls of papaya leaves to the pot after cooking pig food.

During pregnancy, birth and for the first few weeks that follow, make sure the mother (sow) has more food. This helps her to produce healthier piglets and provide plenty of milk for them. Make sure she has a comfortable area that is protected from dogs. The result is that more piglets survive, and they are healthier and will grow better.

Neem leaves are a good supplement to add to pig food but too many cause health problems, and can reduce the sperm count for breeding males. A large handful once or twice a week is good to boost nutrition for overall health. Farmers in some countries use neem leaves or seeds to make a medicine for removing worms and other internal parasites to give to the animal daily for a week.

Clean out the pig house with boiled water containing a big handful of betel palm (Areca catechu) leaves and cover the floor with ash from wood/bamboo fires. This helps prevent fungus and reduces smells. Do not clean out the pig house using bleach as it is very bad for pigs!

Read the suggestions in the chicken health section for further measures that can also help for pigs, such as natural antibiotic medicines and aloe vera for cuts.

Separately house any sick pigs until they are cured to stop disease from spreading.

PIG YARDS

Creating a fenced area for pigs takes time and labour to build, but it saves a lot more time and labour in the future. It also makes your land more productive.

Construct the yard around the pig house and build strong fences to keep the pigs inside. Outside the fence plant some trees and a living fence to provide shade and pig food. The trees will eventually become the fence.

Place rocks on the inside of the fence to help prevent the pigs from digging holes and destroying it. It is a good idea to divide the yard into three or four sections so you can move the pigs from section to section. Grow vegetables in the sections where the pigs are not. Remember that the pigs still need daily food and water.

Pig products

Pigs provide valuable meat, oil and, from their sale, an income, and are great consumers of old food, preventing waste!

Their manure is good for compost and excellent as an ingredient for creating biogas, a system for collecting and using the methane gas which comes from the manure. See Houses, water and energy (**Ch 7**).

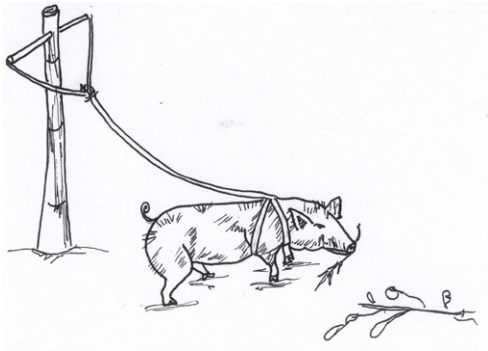
Pigs also love to turn soil over in the hunt for food, and you can turn their habits into labour on your farm.

Pigs are also used in some countries for traditional ceremonies.

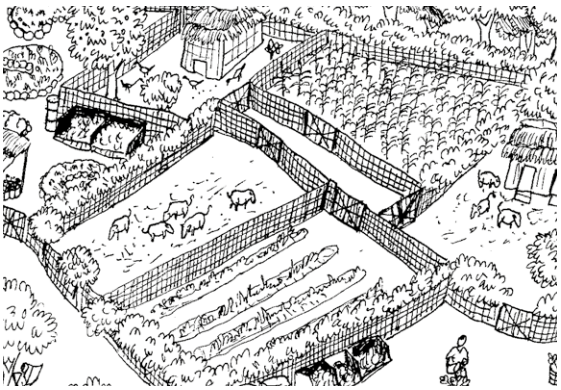
PIG TRACTORS

There are three ways to use pigs as a tractor on your land:

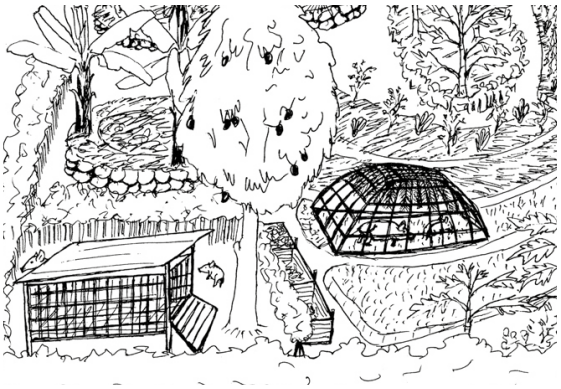
Tie the pigs with rope to a stick so they can clear weeds and fertilise land where you want to plant vegetables or trees. The best method is a pig harness attached to rope and a tall bamboo pole – with a cross section added to top to stop tangling.



Build a good fence around your vegetable land and put the pigs inside to clear the weeds and fertilise it in between crop rotations.



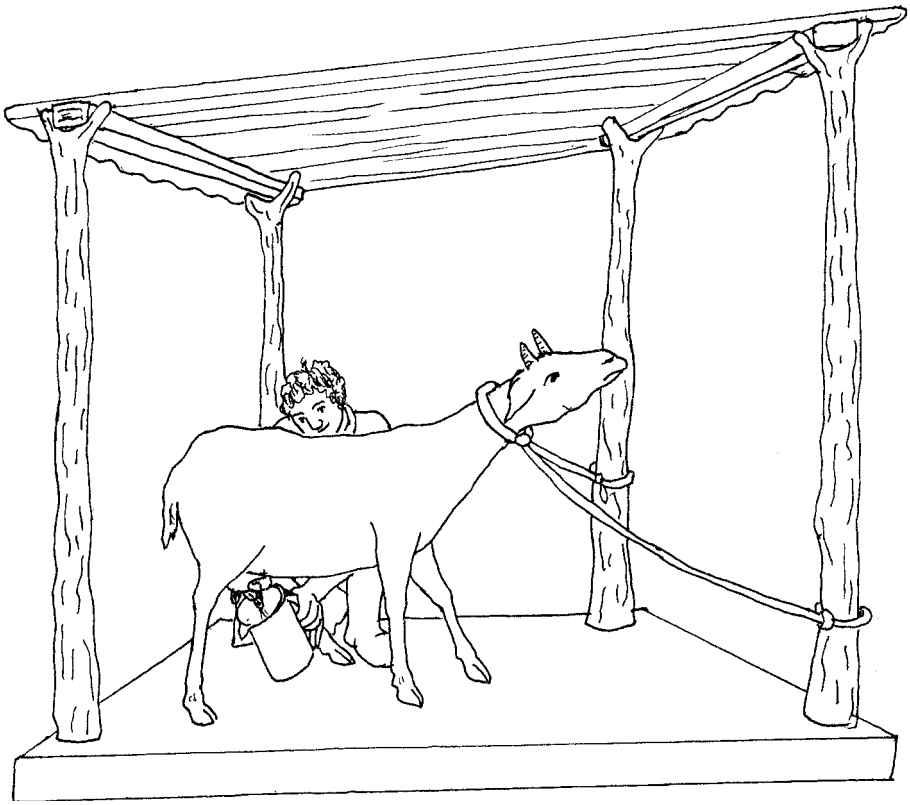
Make a moveable pig house for the pigs during the day. A house four metres long and three metres wide is big enough for three pigs. The house does not need a floor and just palm leaves for the roof to give some shade. Move the house to a new place when they have sufficiently cleared the weeds and fertilised the land.



Look in the Aquaculture chapter (**Ch 18**) for pig and fish systems and the above chicken section of this chapter for more ideas about animal labour systems and combining pigs with chickens.

Goats

Goats are common in many tropical countries, especially regions with drier climates. They are tough and adaptable animals. They give many different products, including milk, and they can be used as labour for weed control and land clearing, but they can also be very destructive to plants and land. They must be well managed to prevent these problems.



Milking a goat

In an established permaculture system, goats can be very productive; however, a small number of goats is usually more productive overall than a large number. Fish, chickens, ducks and pigs are all more productive and work better with other production such as vegetables and fruit trees. For very dry areas goats are the most suitable animals.

GOATS' NEEDS	GOAT PRODUCTS
Food	Meat
Shelter/house	Leather
Water	Milk
Medicine	Manure
Shade	Income from selling goat products
Fences or ropes	Labour – weed control
	Labour – land clearing
	Income from selling pig products

Protecting young trees from a hungry goat

Goats' needs

A simple goat system improves the health and size of your goats, and makes your land more productive.

Start by building a goat house and then create a goat forage area. A plan is important for creating a productive area that provides food and local medicine for the goats, and some food and resources for people.

Sheep's needs are similar to those of goats.

SIMPLE GOAT HOUSES

A goat house provides shelter at night, protection from rain and strong winds, and a place to water and feed them.

The goat-house floor must stay dry in the wet season and be easy to clean. It can be dirt, or a raised slatted floor made of split bamboo or wood. The slatted floor is better for their health and makes it easier to collect their manure.

Add dry grass for the goats to lie on and change it about once a month in the dry season. In the wet season change the grass once a week, and sweep out the area every two days to reduce the risk of disease. The grass contains a lot of goat urine and manure so it makes excellent compost material, mulch and fertiliser.

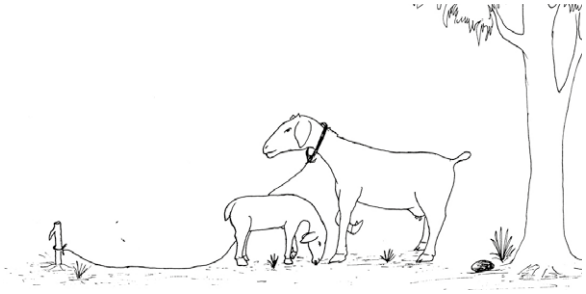
The goat house can be made with or without walls but needs a strong fence surrounding the house. Plant some trees and grass around the goat house to give some shade and provide some food for the goats. Place a water container close by and make sure it continually has fresh water.

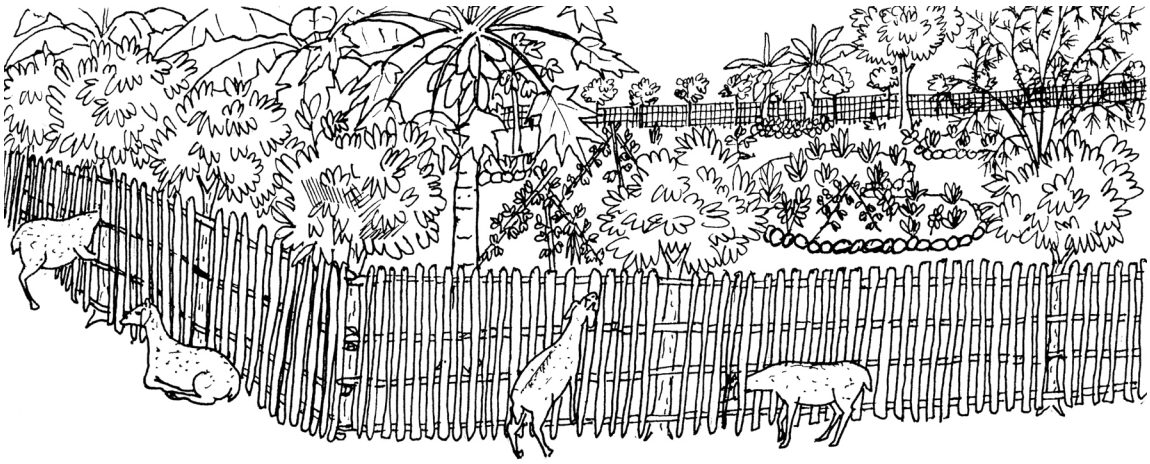
FOOD

Goats are easy to feed because they eat almost any plant and like a varied diet. However, when goats are allowed to roam around looking for food, particularly in large numbers, they are destructive to agriculture and can damage native forests.

Some solutions are:

- Plan ahead and plant enough food for the goats before you introduce them to a specific area
- Fence in an area for the goats to stay
- Tie the goats with rope to sticks and move them when needed
- Build fences around all the vegetable areas and trees





Use a solution that is best for you or a combination of techniques. In the long term it is best to make an area for goats to stay in, combined with controlled grazing. This allows you to make the rest of the land more productive, and protect valuable forests and river systems. However, each day every goat MUST have approximately 10kg of feed.

Give some fresh leaves to the goats each day to improve the goats' size and health. Goats eat most leaves but some are more nutritious than others. Leucaena, moringa, calliandra, sesbania, gliricidia, tamarind, hibiscus, mango, sweet leaf and mulberry leaves are all excellent goat food with a range of nutrients, as are bamboo leaves and grass, including lemon grass.

FOOD ROTATION

A rotation system is a good way to manage goats because it does not put too much stress on any one area. Deciding on the size and shape of each rotation area depends on the number of goats, and the size and shape of the land.

The number of goats per hectare varies depending on the type of feed available:

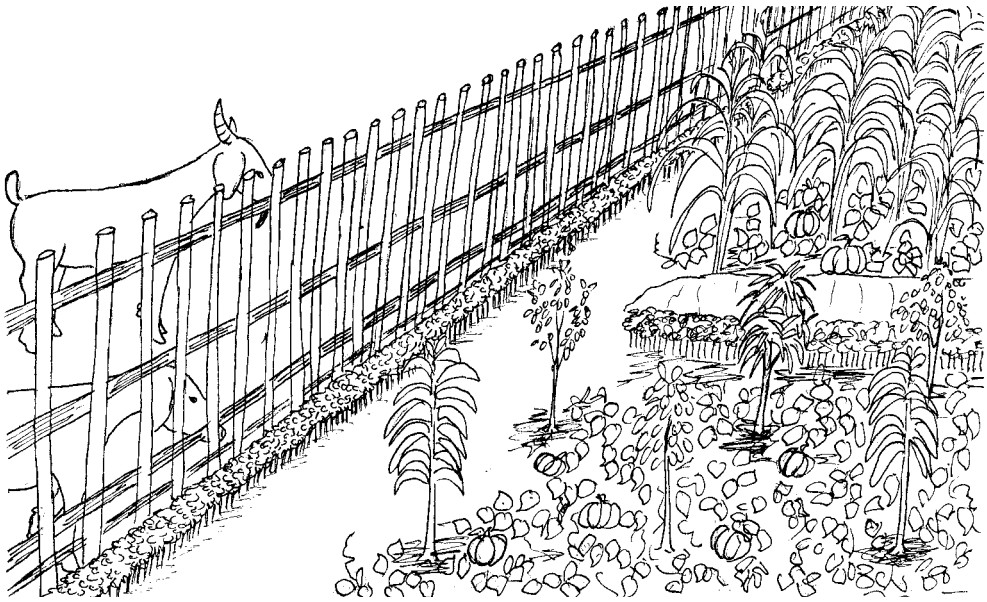
- Good quality grass: three or four goats per hectare – four is the maximum recommended
- Rice paddies after rice harvest: two per hectare
- Poor quality grass or weeds: one per hectare

If you provide additional food from trees, you can increase the growth rate of goats so they are heavier, producing more meat over the same time period. By increasing the quality of grass and adding ground cover legumes you can increase the number of goats per hectare.

SMART IDEAS:

- Create a sustainable low-cost system by planting many trees – which are better for the environment and more resilient to climate change – to provide the goats with food, medicine, shade and fencing.
- Give seaweed, where available, to goats once a week to supplement their vitamin and mineral intake. Fish bones (dried and powdered) are also a good source of sodium, calcium and phosphorus.
- Goats do not like eating food that has dirt on it, so hang their food from branches from a fence or make a raised feeding floor out of split bamboo on which to put the fresh leaves.

Planting living fences to divide up the goat areas is good because they can also provide food. However, the goats eat them if they are introduced too early. A good solution is to make a fence, and grow a living fence on the outside. The fence can last for a few years allowing time for the living fence to become established and replace it. Another option is to plant a living fence with trees that goats do not like eating.



Fence with living fence growing inside it

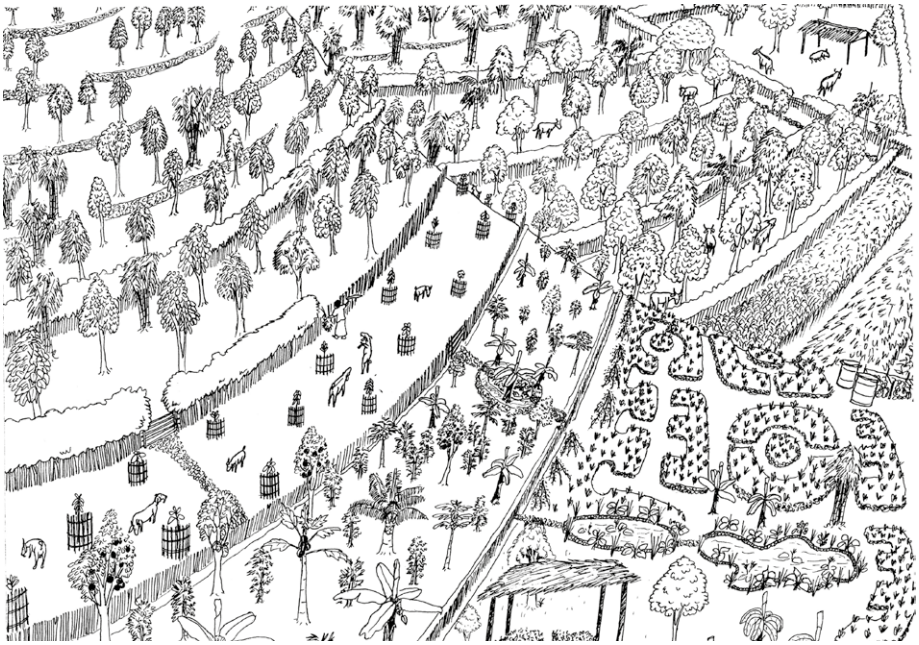
Benefits of rotating goats:

- Moving the goats from one area to another before they eat all the grass and vegetation allow them to grow again
- They control weeds and provide fertiliser
- The goats do not damage any other crops or land

SMART IDEA:

Collect and spread seeds of native legumes, including ground covers, beans, clovers and other small plants (but not the poisonous beans!) This improves the soil, helps the grass to grow better and provides high-quality feed for the goats.

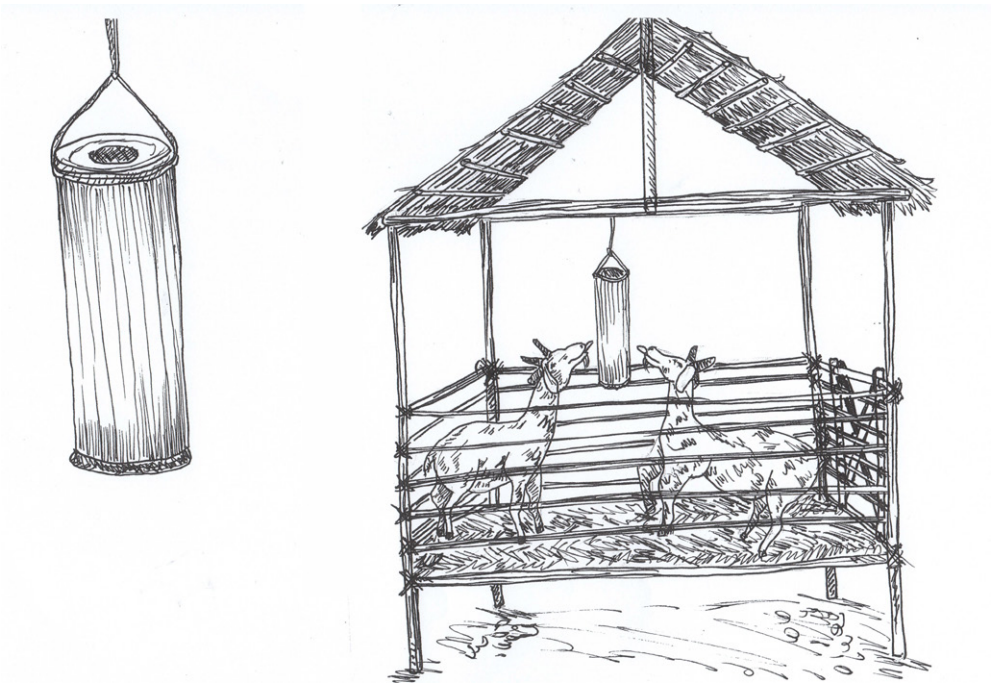
Plant fruit and other production trees within the rotation areas and protect them well from the goats. The goats then help to weed and fertilise around the trees.



Goats as part of an established agro-forestry system

HEALTH

Sea salt is very important for goats' health and increases their appetite. Cut a section of bamboo, remove the skin, fill it with sea salt and hang it in the goat house. The salt soaks through the bamboo and the goats lick the bamboo when they need salt; goats always come back to where there is salt!



Add green papaya seeds and mulberry branches regularly to the goats' food as these help to control worms. Keep mothers and newborn kids in a house or yard that is protected from rain and wind. More kids will survive after birth and the chances of sickness for mothers and the kids are lower.

Coccidiosis – one of the main diseases that affects goats, sheep and chickens – is caused by a microscopic protozoan parasite. Coccidia usually exist without a problem in the intestines of most goats, but if living conditions are unhealthy and the weather is bad, the parasite numbers can increase to a level where it can kill them. Usually this is at the end of the wet season when there are strong winds.

The best cure for coccidia is prevention:

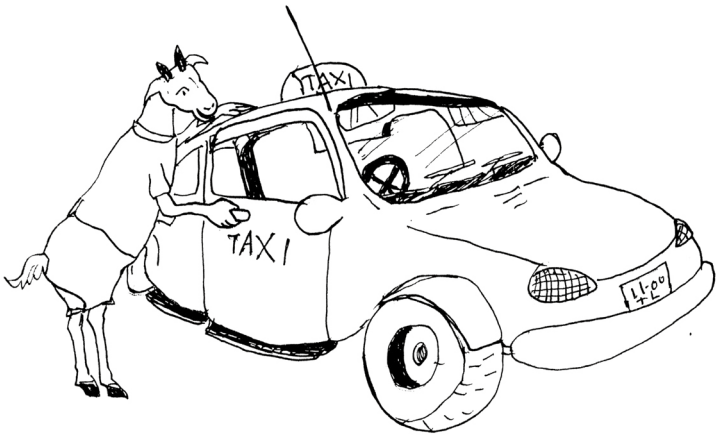
- Do not keep too many goats in the yard.
- Clean out the goat house regularly in the wet season – every day or two – as wet goat manure increases the risk of the disease spreading. Use boiled water containing a big handful of betel palm (*Areca catechu*) leaves, and cover the clean dry floor with ash from wood/bamboo fires. This helps to prevent fungus and reduce the smell. Do not use bleach as it is bad for goats!
- Put some dry grass on the ground in the goat house and burn it to kill coccidia and worms living in the soil. Doing so once or twice each wet season helps to maintain hygiene, but be careful if you have a grass roof!
- Clean out the water containers regularly to prevent contamination from goat manure.
- Protect the goat house from strong winds, and plant wind breaks to reduce the wind.

Immediately separate any sick goats from the rest to stop disease from spreading.

A large handful of neem leaves is a nutritious goat food supplement if given once or twice a week. However, too many leaves cause health problems and can reduce the sperm count for breeding males. Farmers in some countries give goats a neem leave/seed-based medicine for killing worms and internal parasites daily for a week.

Read the chicken health section for further measures that can also help goats, such as natural antibiotic medicines and aloe vera for cuts.

Goat products



Goat products include meat, milk and manure from which you can earn an income by selling them.

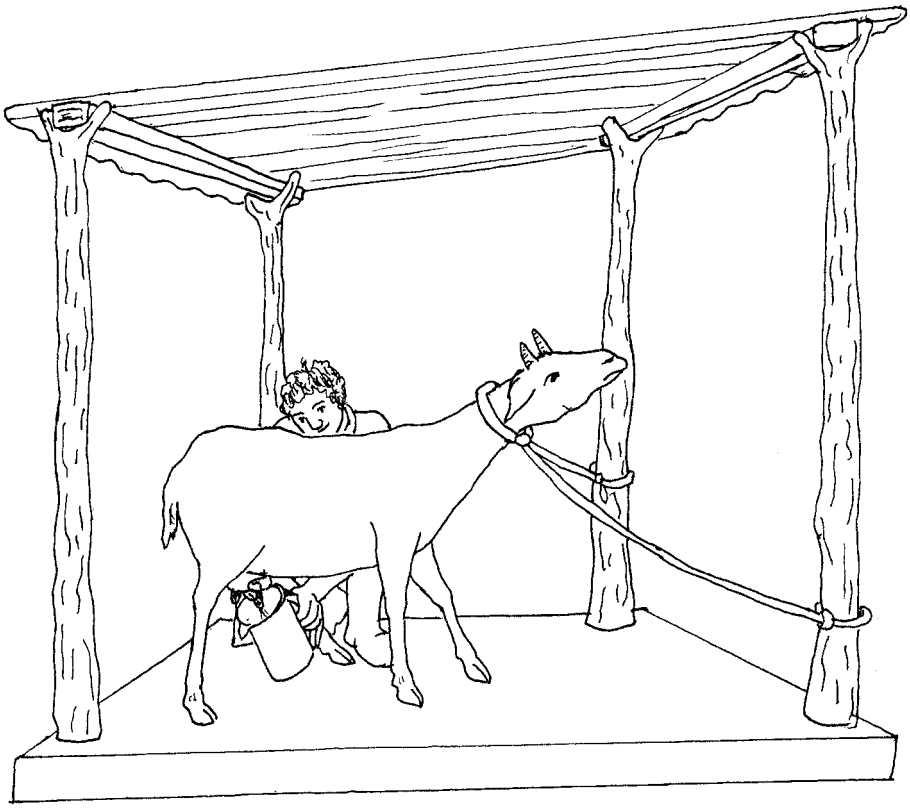
GOAT'S MILK

Goat's milk is a healthy alternative to cow's milk for people to drink, especially children. It is good for people with asthma as it produces fewer allergies, and it contains smaller fat molecules making it easier to digest. Goats produce milk all year round, from which you can make cheese and yoghurt.

Milking goats requires daily dedication, and good land design and management. Not all types of goats produce milk, and for larger quantities of milk the goats require more food. Growing trees for goat food is essential.

Milking goats must be done properly, cleanly and carefully by people who have received training or the goats can get sick or be permanently hurt. The goats also need training to get used to the process as they require milking every day. You need a milking room and some equipment, which must be kept clean and germ-free.

If the milking is done properly it can be worthwhile, providing milk for drinking, cheese making, trading or selling. Your local agricultural workers or community members might have information and read the reference chapter to find further sources.



MANURE

A goat house provides you with a lot of manure to add to liquid compost and compost. It can also be dried and spread around corn, cassava and other crops to improve production.

LAND CLEARING

Goats can clear weeds from areas of land you want to use to grow crops or trees. They provide good labour, but just make sure they do not clear your neighbours' land too!

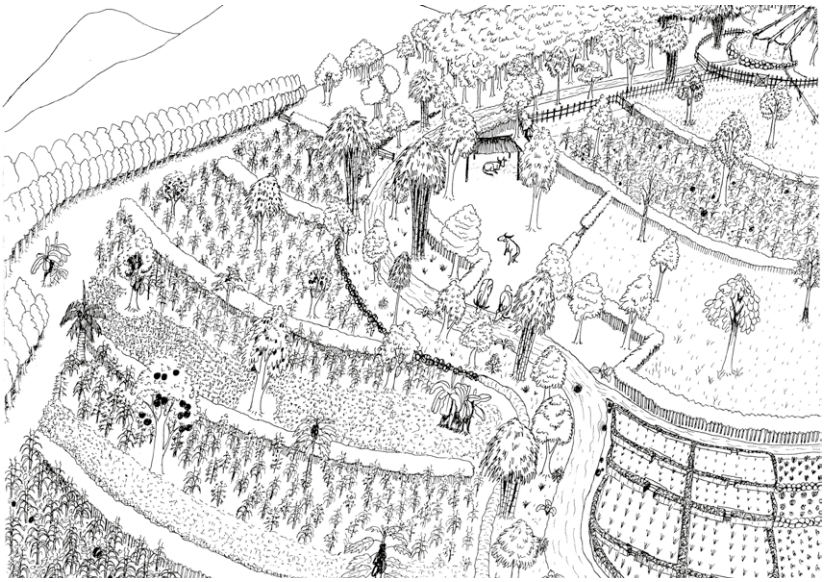
Cows

Cows are important culturally and economically, and their meat and dairy products are part of many people's diets. However, to be healthy and productive they need a large area of land, and a lot of food and water.

Design land management systems that combine cows with other land use, such as tree crops, bamboo, sustainable agriculture and other animals, as well as protecting forests and water sources. Make the most use of all cow products, including their ability to manage vegetation.

Cows consume a lot of resources. If they are poorly managed, they are bad for the environment and water security, and they produce methane gas that contributes to climate change. However, if they are part of a sustainable integrated system, cows have a positive impact on a community and its environment.

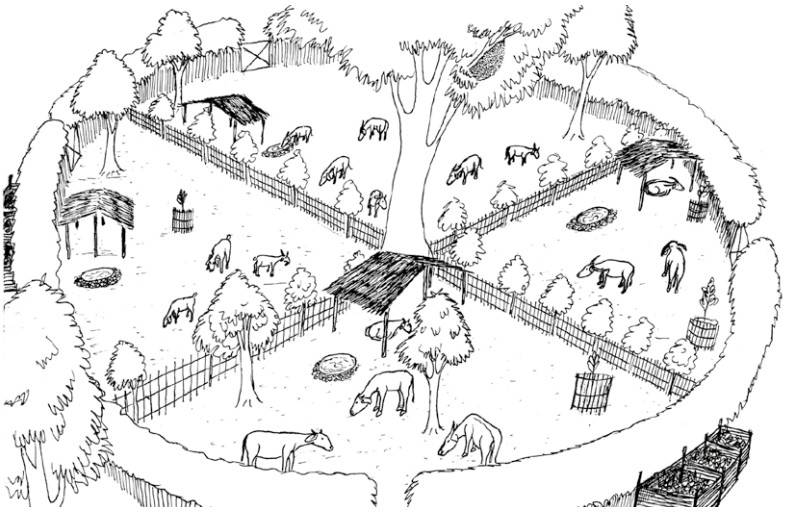
If you improve the grass quality, grow ground-cover legumes for the cows and create windbreaks, you can raise more animals on the same amount of land. Growing a lot of trees for cow fodder is a vital part of a sustainable cow management system and they will also be healthier, larger and grow faster. The best cow food trees to plant are leucaena, gliricidia, sesbania, calliandra, moringa, albizia and many others.



Cows as part of a sustainable agriculture and agro-forestry system

The trees can also serve as fences. A windbreak improves the growth and quality of grass for cattle feed, reduces the stress on a cow and its energy use and provides shade. Read how to create windbreaks in the Permaculture design strategies and techniques chapter (**Ch 3**).

COWS' NEEDS	COW PRODUCTS
Food	Meat
Water	Milk, cheese, yoghurt and other products
Shelter/house	Manure, as fertiliser, fuel and as a biogas ingredient
Medicine	Leather
Shade	Labour – grass control
Fences or ropes	Ceremonial needs
	Income from selling cow products
	Biochar ingredient – bones, manure
	Transport



Animal yards divided up for cows, goats and buffalos

Cows' needs

FOOD

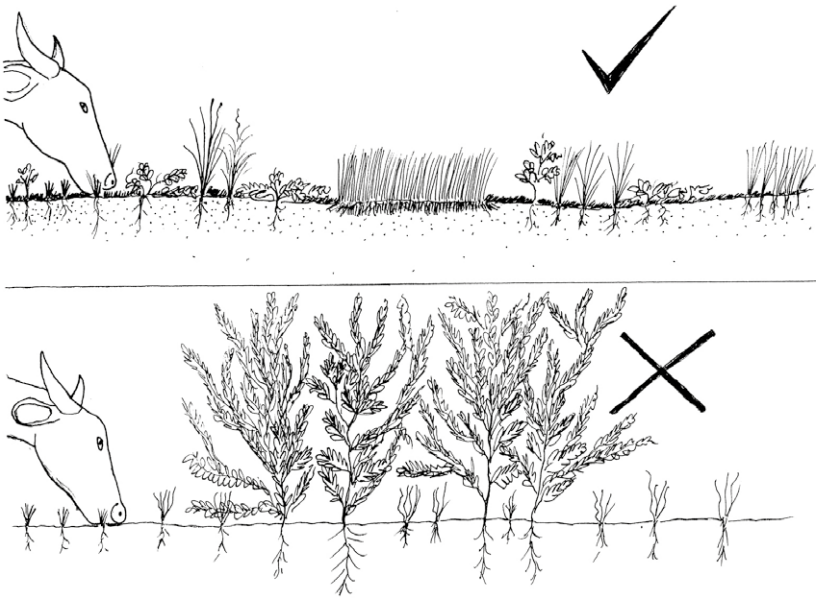
Cows mostly eat grass and legume ground covers and need a large land area for feeding. They can also eat tree leaves such as those listed to above. Leaves from leucaena, gliricidia and calliandra trees create a calcium deficiency if used as the main stock food, so the cows need lime in their diets to balance this. Seaweed or dried and powdered fish bones supply some lime as well as other minerals.

Grasses and legume ground covers

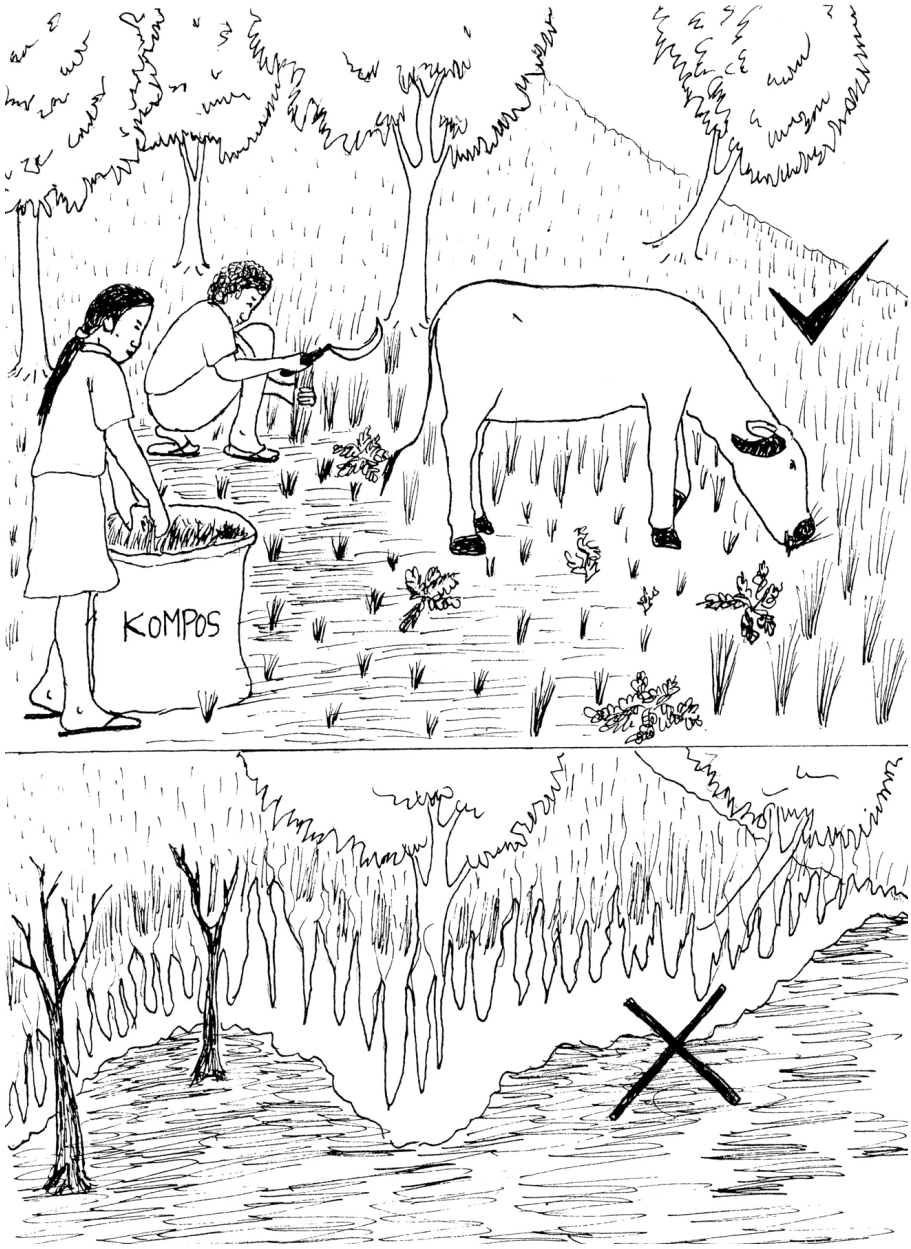
Good quality grass and legumes result in larger, healthier cows. Manage the land you use for feeding cows to improve the quality and types of grass and legume ground covers.

Techniques for good management:

- **Collect and spread the seeds of legume ground covers.** Introduce new legume plants, such as clover, but local legumes are more likely to grow better. Be careful not to introduce new weeds! It is important to mix legume plants with grass because they provide food containing vital proteins and minerals. They also add nitrogen to the soil that helps the grass to grow better.



- **Stocking rate:** The stocking rate, or the number of cows per feeding area – usually a hectare – is very important. The average stocking rate for low rainfall tropical regions is one cow per two hectares for good feeding land, and a maximum of one cow per hectare for high rainfall tropical areas. It is approximate but the main idea is that the cows have a big enough feeding area or move elsewhere before the remaining grass is overgrazed.
- **New growth**: Introduce cows after the grass/legumes have a growth spurt. This occurs after the grass/legumes are first cut or eaten by animals. Move the cows on after the first cut – the most nutritious for cows – so they do not damage the cut grass/legumes and prevent regrowth.
- **Frequent rotation:** Rotating higher numbers of cows more frequently from area to area, rather than rotating lower number of cows less frequently, is much better for the cows, the growth and diversity of their food, the soil and the environment. Use an order for rotation feeding; mothers and calves first and other cows afterwards. Mothers and calves need the best food to grow well and stay healthy.
- **Fertilising:** Fertilising a large area of land is either expensive or takes a lot of time. Chemical fertilisers help in the short term but can create long-term problems and are expensive. Organic fertilisers provide better results in the long term and are cheap if you make your own. Liquid compost, biochar and bacterial activators (see Soil **Ch 9**) accelerate soil improvement and are easier to apply over large areas. Fertilising at the beginning of the wet season improves the amount and quality of fodder. Good fodder increases the amount of meat on each animal, which more than makes up for the cost or time used for fertilising. Improving soil quality through good animal and land management is best long-term solution.



Warning about burning: Burning creates problems because it increases the amount of low-quality grass and weeds – which grow back faster after burning – and decreases high-quality grass and legumes. Burning often weakens the grass, eventually killing it, and legume ground covers die. Burning in the middle of the dry season is especially bad as the vegetation is already under stress from lack of water. Areas where cows eat regularly should not be burned.

Weed control: Weeds are a big problem for cow-grazing land, and they reduce the amount of productive land.

Techniques to reduce weed problems:

- Create a long-term weed management plan with yearly steps to achieve. This might include stronger, more careful measures to remove weeds for the first year or two, but the plan should always result in self-managing, sustainable and organic systems.
- Plant velvet beans, other ground cover beans and cowpeas.
- Mulch the land with cut grass and weeds.
- Selectively remove weeds **before** seeding time. Any weed removal must be followed by planting good grass and legume seeds.
- Improve the soil quality and PH levels.
- Some other techniques, explained already, are:
  - Using correct stocking rates.
  - No burning.
  - Rotating feeding land for cows.

Dry grass

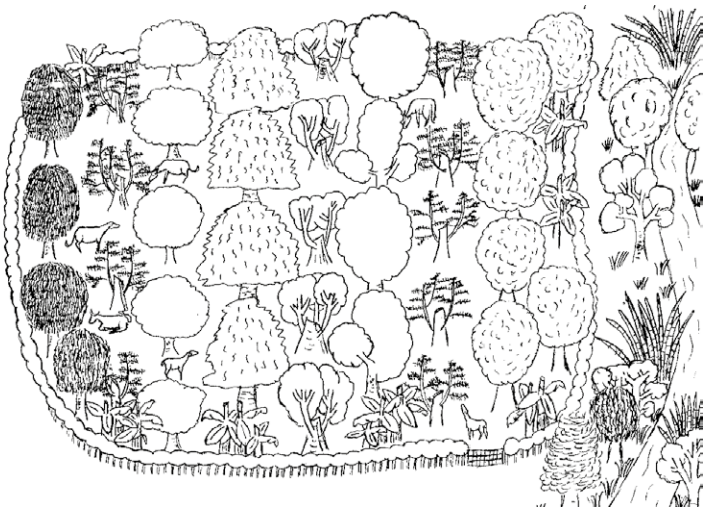
Dry grass is also valuable cow food. It is not as good as fresh grass but still provides sufficient feed, and is better than no grass at all. The dry grass also protects the soil from erosion and wind in the dry season. Remember that burning destroys the grass!

Silage

For intensive feeding and where enough material is available, silage provides valuable animal fodder during the dry season. Silage is produced by harvesting grass, grains and even palm leaves and chopping up fresh green plants, then storing the material in airtight containers to allow fermentation. The fermentation process preserves the food and a lot of the nutrients, as well as making it more digestible. Look in the reference chapter for more information on making and using silage.

Trees for feed

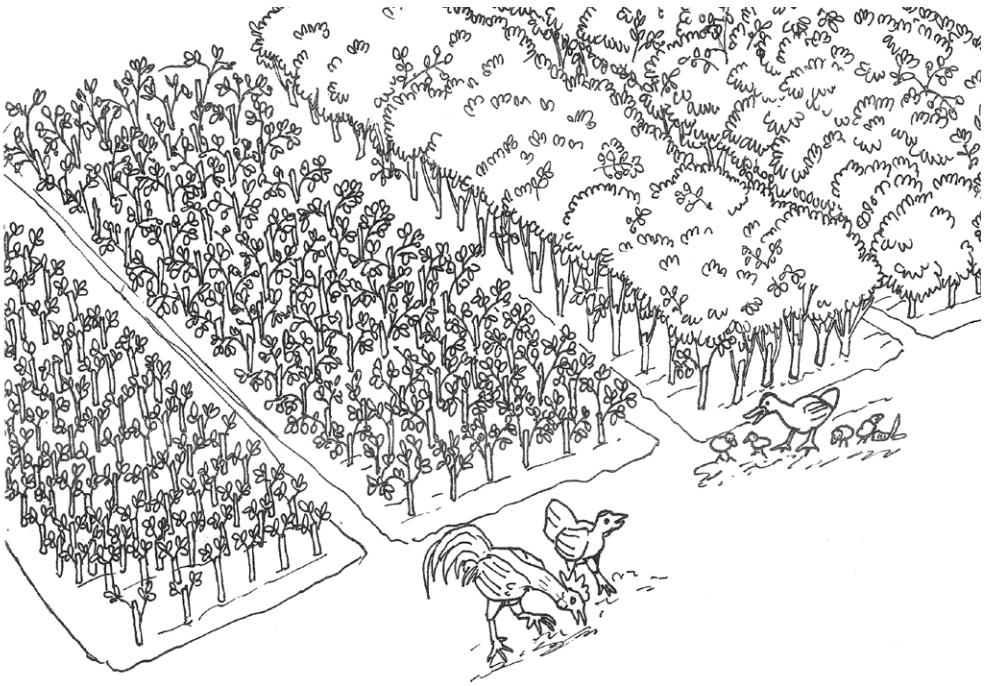
In a well-planned system growing trees provides cow feed, shade, wind protection, fencing, medicine, soil improvement and more. Trees help to increase the stocking rate and improve the living conditions for cows. They increase resilience to climate change by providing food when grass has died, improve the environment and are low cost.



Bamboo leaves and lemongrass are excellent food for cows and lemon grass can be used as a training device treat.

Moringa

For a high-quality cattle food, grow moringa, especially because it is also drought tolerant. Studies have shown that feeding cows either fresh or dry moringa leaves as part of their daily food increases their weight gain and milk production a lot. Recommended amounts are 10kg or more of fresh leaves or 2–3kg of dried leaves per day.



Growing moringa for cow feed

Be careful: Do not just use one type of plant to feed cows. It is important to vary their feed but still ensure they have their daily amount of high protein, high vitamin and mineral foods. If you can, give seaweed to cows once a week to supplement their vitamin and mineral intake.

WATER

Cows need a daily continuous supply of fresh water in their yard. If the cows have access to rivers and springs, make sure the water sources are properly protected from the damage they can cause – the cows should only access the water from a few well-managed places.

Cows in a well-managed system

COW YARDS

Keep your cows in a small fenced area at night. The yard size depends on the number of cows you have and is best built close to where the cows feed. Make sure to build the yard on ground that dries quickly in the wet season. Cows do not need shelter but build the yard under some large trees, if possible, to provide some shade and protection from the rain. A simple roof or large trees keeps the ground drier in the wet season, improving the cows' health. Always keep a good layer of grass on the ground.

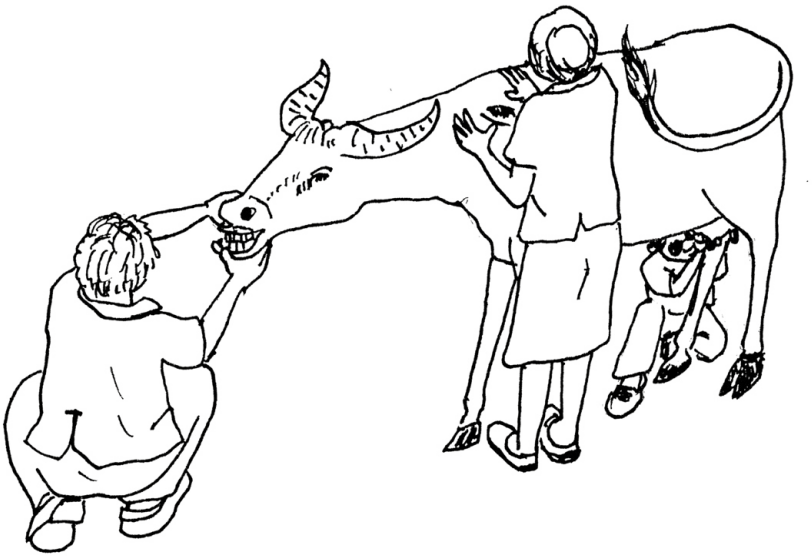
SMART IDEAS:

- Use a living fence, which can later be cut back for cow feed, to make the yard.
- Make a compost area next to the cow yard, so the manure can be mixed immediately with grass, rice husks and other compost materials to make compost.
- We strongly recommend never keeping cows permanently in very small yards. Cows need to walk around. If they are kept in yards with little or no grass, the cows MUST have at least 10 per cent of their bodyweight in feed EVERY DAY, but they still need space to walk around.

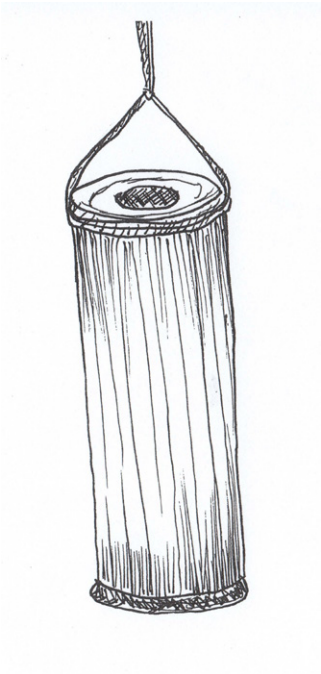
SHADE

Cows need shade to be cool and happy as too much sun is not good for them. Remember, a happy cow is a healthy cow!

HEALTH



Here is a list of suggestions to keep your cows in good health:



- Keep them away from wet, swampy areas.
- Provide a dry space for them in the wet season; being constant wet is bad for their health.
- Clean their yard regularly to prevent disease from spreading.
- Treat any sores on the cows quickly to stop infections and worms. Aloe vera is a good treatment.
- Give them green papaya seeds regularly to prevent and control worms.
- Bot and other biting flies are a major health problem. Cows use a lot of energy trying to shake them off and can actually lose weight as a result. Chickens are a great solution! Run chickens through an area straight after cows and the chickens eat a lot of the fly larvae. Another natural solution is to create small areas where there are opportunities for frogs and toads to breed as they also eat the fly larvae.
- Keep mothers and newborn calves in a house or yard that is protected from rain and wind to help more calves to survive and reduce the chances of sickness.
- Sea salt is very important for their health and increases their appetite. As suggested for goats, see the goat health section for how to ensure cows get enough salt.
- Separate any sick cows immediately to stop disease from spreading.
- Neem leaves are a good supplement in cow food but too many cause health problems. See more information in the goat section and ask experts in your region for neem and other natural remedies

Cow products

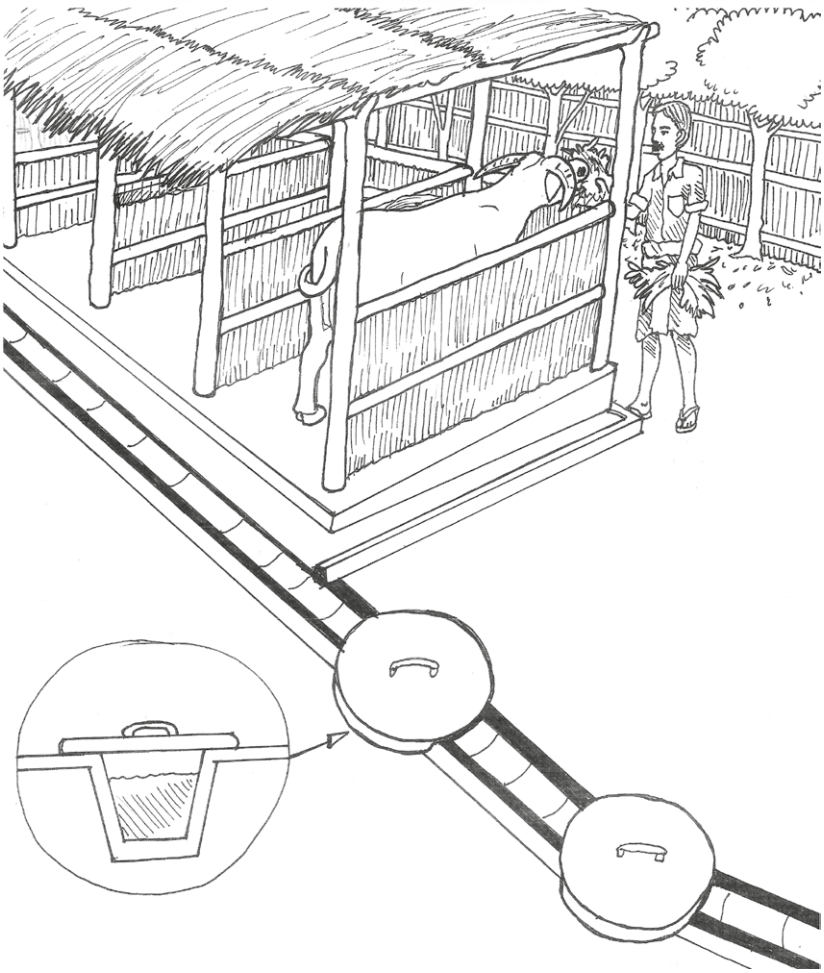
Cows provide meat, especially for special ceremonies. Selling a cow or its products also provides an income; in many countries they are a big asset, like money saved in a bank.

By integrating cows into different systems you can reduce your labour and create more resilient, healthy systems and many different products.

MANURE

Cow manure is excellent for vegetables and fruit trees and is easier to collect from a cow yard. Be careful with fresh manure because it can burn plants, especially young ones. Manure is better if it is dried or made into compost or liquid compost before using it: Soil (**Ch 9**) has different compost methods.

Cow manure is an excellent ingredient for biogas systems. Fresh manure is also used to line dams and fish ponds to stop leaks.



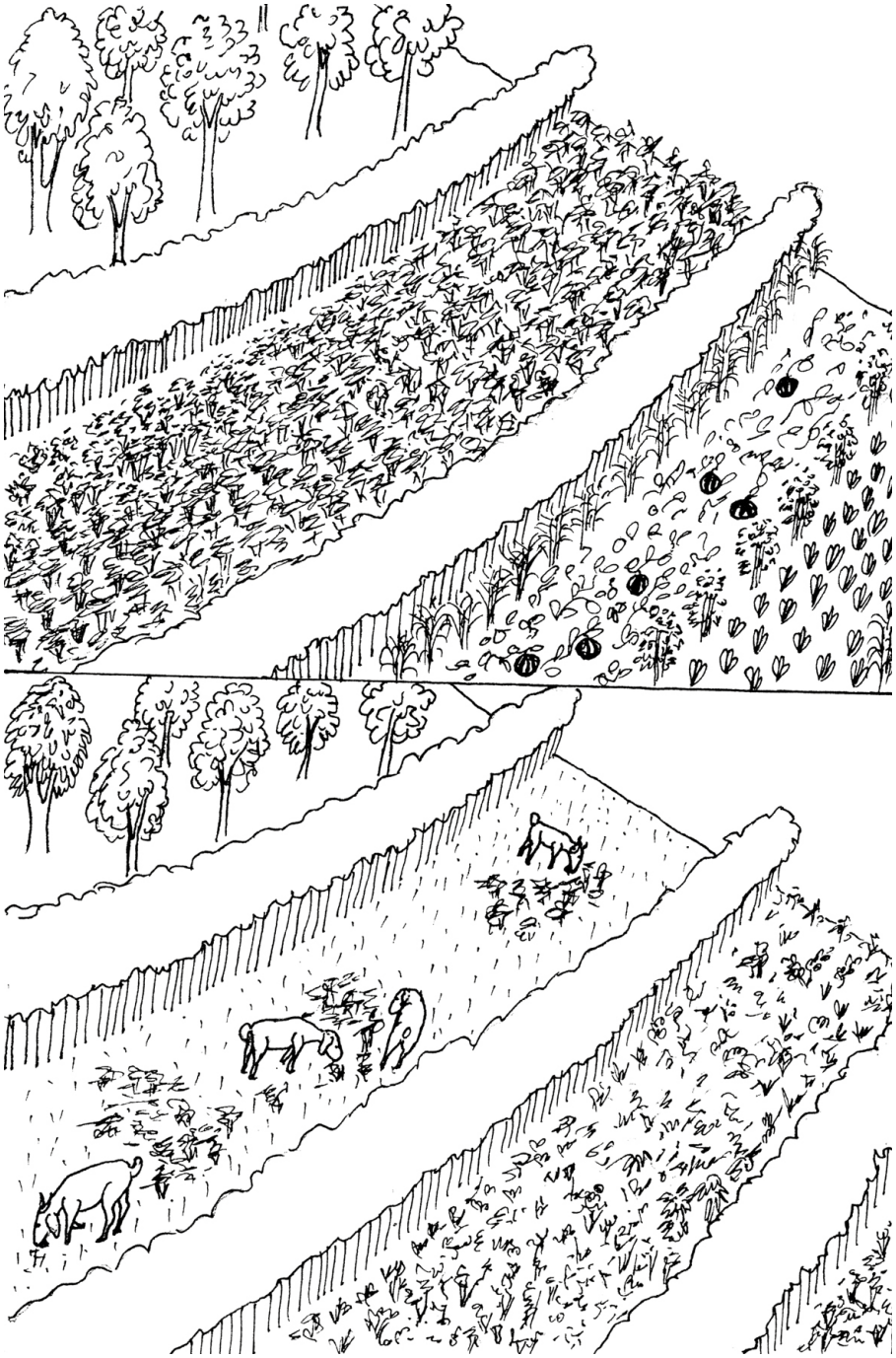
Night cow yard used for collecting cow urine and manure for liquid compost, compost and biogas

ROPE AND STAKE

Roping a cow to a stake anchored in the ground is a simple method to keep a small number of cows where you want them. Move the cows often to give them fresh grass, to prevent them from overeating and to reduce soil compaction. Make sure they always have access to water.

COWS AND SUSTAINABLE AGRICULTURE

After harvesting rice, corn, sorghum, beans and other crops grown in larger quantities, let cows onto the land to graze. They feed on the stalks, leaves and weeds, fertilising as they go. Make sure the rice paddies are dry enough for the cows to walk over.

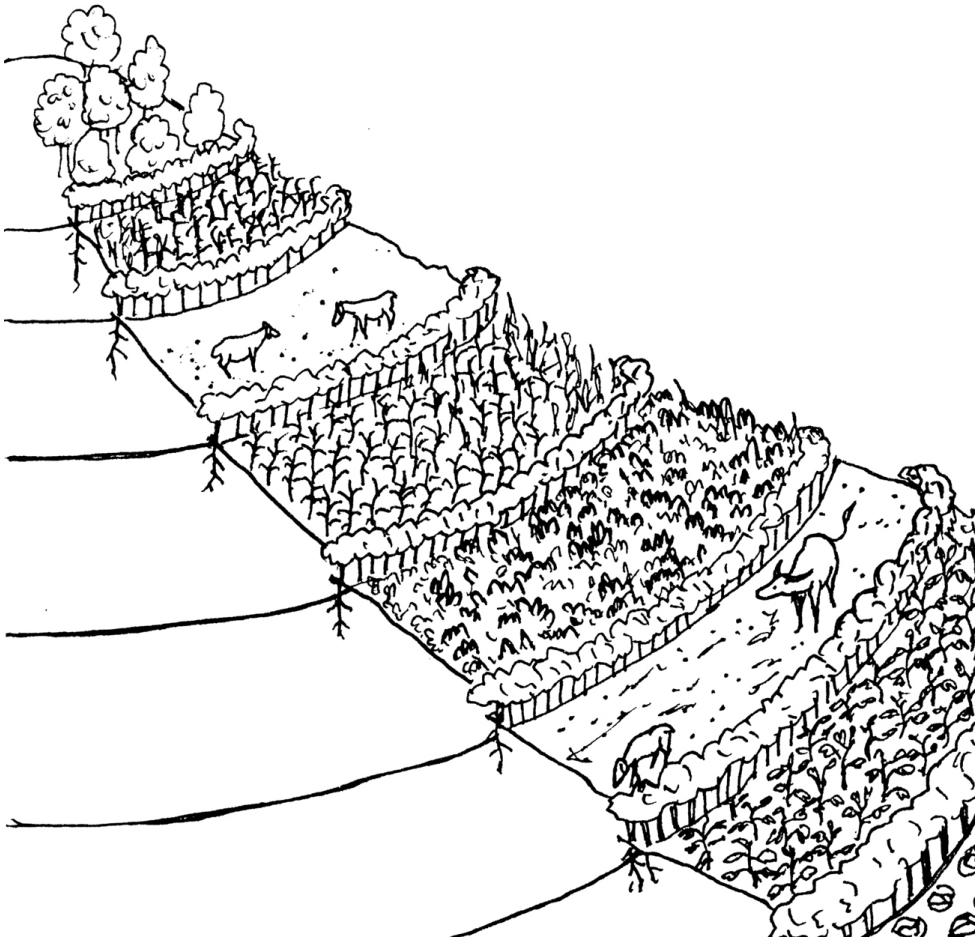


Cows eat a green manure crop as part of a sustainable agriculture soil improvement technique

AGRO-FORESTRY, ORCHARDS AND COW INTEGRATION

Combine cow (and other animal) feeding with rows of productive trees and crops such as corn, cassava and taro. Living fences divide up the land into rows and keep the cows (and goats, sheep and buffalo as well) away from trees and crops.

It is important to plant the trees on contour with the shape of the land. On sloped land use swales or tree terraces to improve the system and stop erosion. The feeding rows should be between five and ten metres wide.



Read Permaculture Design (**Ch 3**) for techniques on making tree terraces and swales. When the fences are established, rotate the rows between the cows and growing crops. Do not introduce cows into the rows until after the tree leaves are above eating height. This system creates high-quality feeding land for cows. The living fences and trees between the rows provide cow food, fruit, nuts, wood, bamboo and many other products.

WILD LEGUME PADDY ROTATION

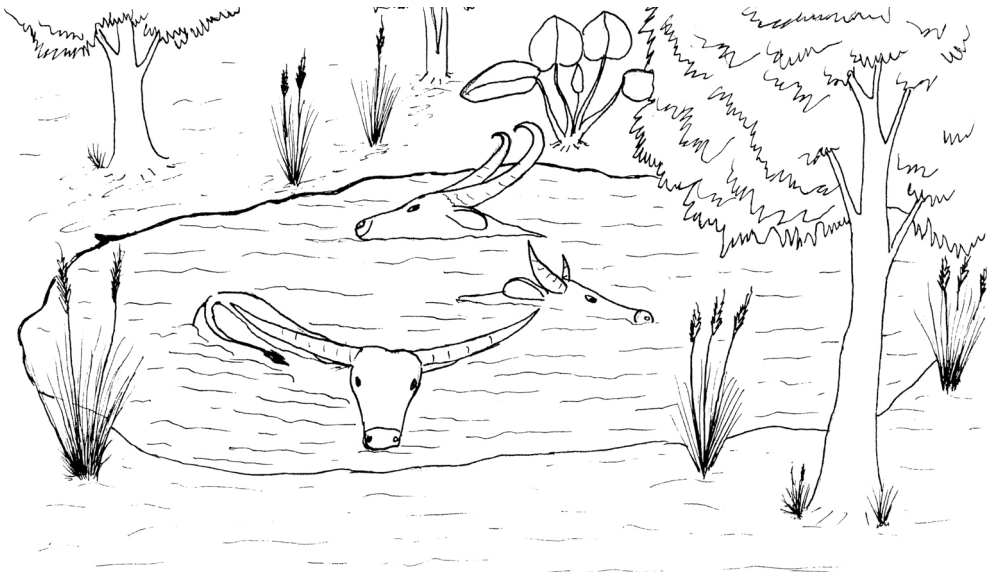
Read in the buffalo section about this technique; it applies to cows as well as buffalo.

SMART IDEAS:

- Plant animal medicine trees, too, to provide traditional medicine if an animal becomes sick.
- Be very careful not to let cows spend too much time on land that you want to use for growing crops. As they are very heavy, they make the soil very hard when they walk on it too often. Compacted soil makes digging a lot harder and reduces the size of your crop.

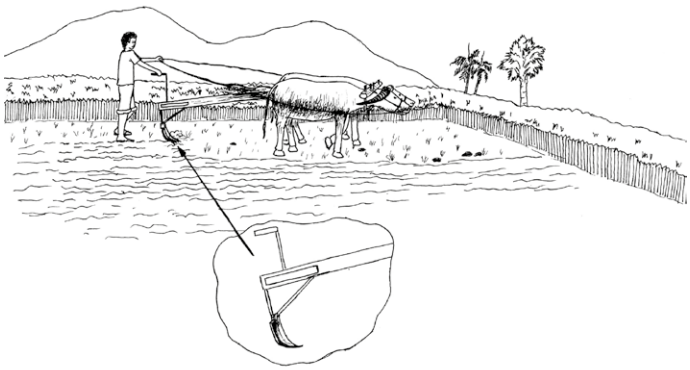
Buffalo

Buffalo are important to many tropical countrys' cultures, economies and diets. And, like cows, they need a large area of land and a lot of food and water. Buffalo are good animals for wet, muddy conditions and can eat in areas where cows cannot.



The biggest benefit from buffalo is that they plough rice paddies and fields. Buffalo growth rates, size and health improve by providing high-quality grass and fodder, growing food and shade trees, and creating windbreaks where the wind is strong. These ideas also increase the number of buffalo kept in an area.

BUFFALOS' NEEDS	BUFFALO PRODUCTS
Food	Meat
Water	Milk
Shelter/House	Manure for fertiliser, fuel and biogas
Shade	Leather
Water hole	Labour – ploughing paddies and fields
Fences or ropes	Labour – grass control
Medicine	Horns
	Ceremonial needs
	Income from selling buffalo products
	Biochar ingredient – bones, manure
	Transport



Buffalo's needs

FOOD

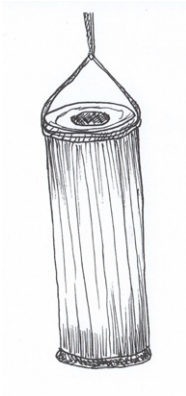
Buffalo eat similar food to cows but they can live on land that is much wetter than cows can. Read the cow food section for different types of feed and land management techniques.

WATER

Buffalo need water daily to be healthy.

HEALTH

Sea salt is very important for their health and increases their appetite.
See the goat section for how to give salt to buffalo.



Shade and a water hole are important for buffalo health; they have fewer health problems than cows in the wet season because they love water and mud.

Keep the buffalo yard clean, and provide good food and water. Treat any sores quickly to stop infections, especially cuts on buffalo used for ploughing. Use cloth or other pads under ropes, harnesses or plough frames to prevent cuts and sores. Aloe vera helps; there are many other traditional medicines as well. Give green papaya seeds regularly to prevent and control worms.

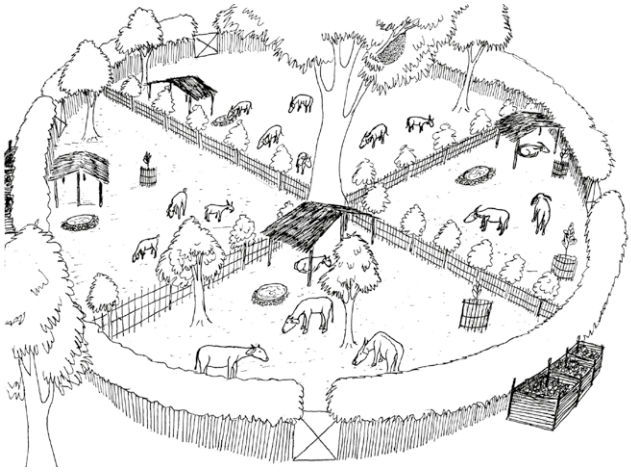
Neem leaves are a very good supplement in buffalo food as they are for cows and goats – see the goat section above for further details.

Keep mothers and newborn calves in a house or yard that is protected from rain and wind to help more calves to survive and reduce the chances of sickness. Separate any sick buffalo immediately to stop disease from spreading.

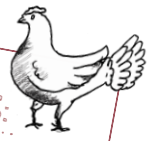
BUFFALO YARDS AND SHADE

Buffalos do not need shelter at night but a simple structure to give shade during the day is beneficial for their health.

If you keep the buffalo in a fenced area each night, you can collect and use the manure as fertiliser for your crops and fruit trees. Place the yard in a dry area, if possible, to maintain good health.



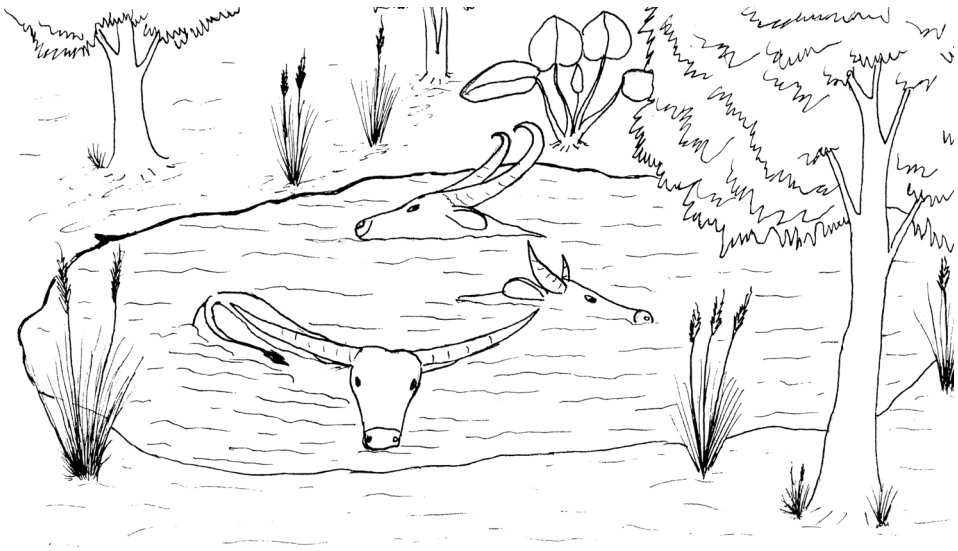
SMART IDEAS:



- Use a living fence for the yard made from trees that provide food for the buffalo.
- Place the fenced area under some large trees to provide shade. Plant some fruit trees next to the buffalo yard to benefit from the manure's extra nutrients.

WATER HOLES

Buffalos need a water hole to keep cool during the day or they suffer a lot from the heat and sun. Do not have a waterhole above a spring or community water supply because bacteria from their manure can contaminate the water.



Buffalo products

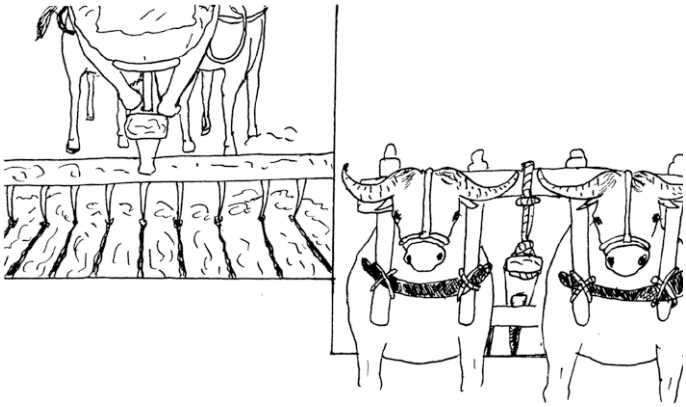
Buffalo provide meat and an income from selling their products – as cows are, buffalo are like savings in a bank. They are very important for celebrations and ceremonies, and have other advantages, especially when they are integrated into other systems.

Labour

Buffalo can be trained to plough fields and rice paddies. They cannot work for too long in direct sun, and regularly need water and breaks in the shade. Trained buffalo can also transport farm resources over short distances.

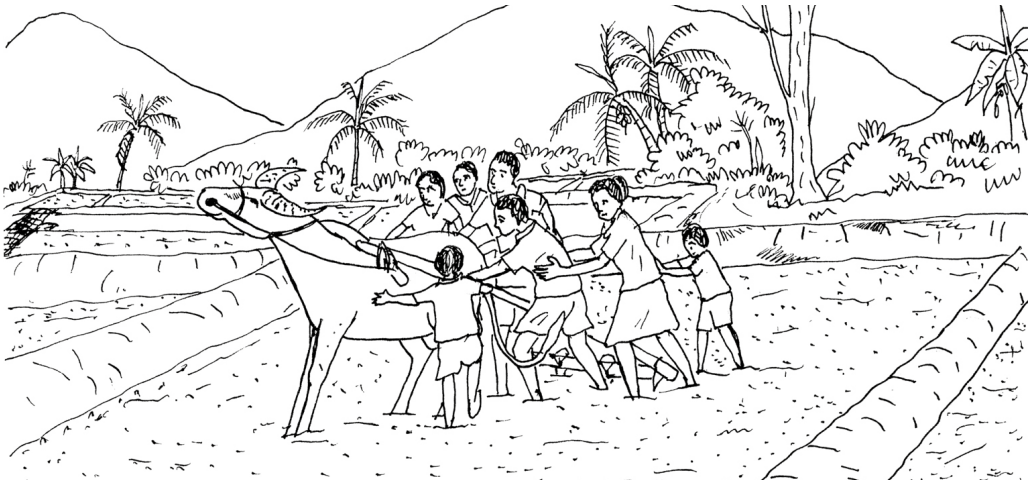
Buffalos are excellent for this work because:

- Once a buffalo is trained it can do the work for many years, as long as it is healthy.
- They are **a lot** less expensive to buy and easier to maintain than a tractor!
- Almost anyone can learn how to work with a buffalo.
- They plough steep land and other areas that tractors cannot access or plough.



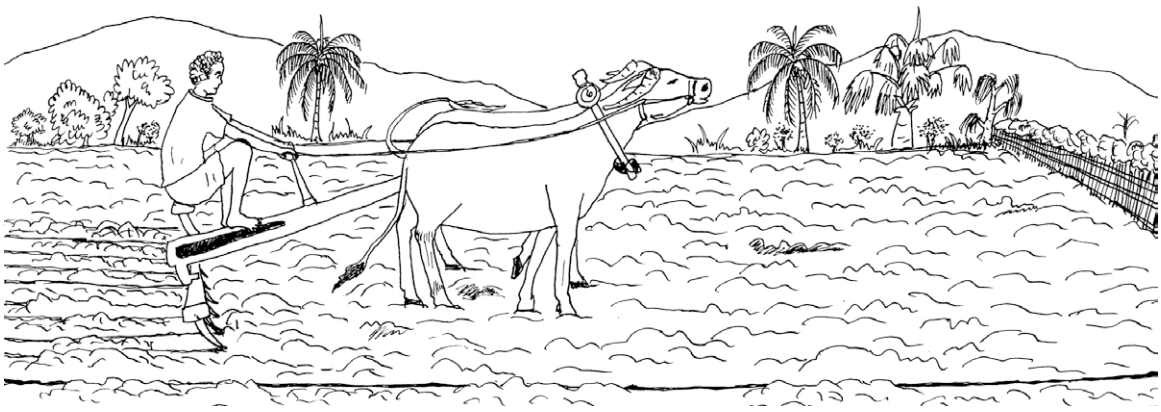
A GUIDE TO BUFFALO TRAINING

Adapted from a publication called *LikLik Buk: A Source Book for Development Workers in Papua New Guinea*, these notes are a guide only and any attempt at training buffalo should be with buffalo trainers or workers experienced in using buffalo ploughs.



Before training!

1. The first lesson is for the animal to untangle itself from its own rope. This usually takes a week or two. Tie the rope around the horns or neck first, but through the nose later.
2. It is good to have someone handling the animal every day, preferably the same person, who becomes a "friend".
3. It is better not to train the buffalo to work by having a person lead it from the front. If you do, remember that the buffalo must learn to work with the person behind. Be patient.
4. For direction training (go left or go right), the trainer should always be on the left and at the rear. The usual sign is a steady pull on the rope to go left and a gentle tug to go right.
5. After some direction training the buffalo can also learn to carry a person on its back.
6. First, and easiest, hitch the animal to a small cart. Then use a plough, and finally a large cart. Slowly get the buffalo used to pulling and its skin around where the ropes touch will become tougher.
7. Incentives are very important. Let untrained or difficult buffalo train around other familiar buffalo, especially during direction training. Train animals when they are partly hungry, and after their work give them a bath, some water, salt and good grass. Lemon grass is a good reward.
8. Most buffalo try to resist at first but the trainer has the control and the buffalo has to accept it. Treat it firmly but fairly – do not use force unless you have to.
9. Buffalo need shade when they are hot and lots of water for drinking and bathing.



After training!

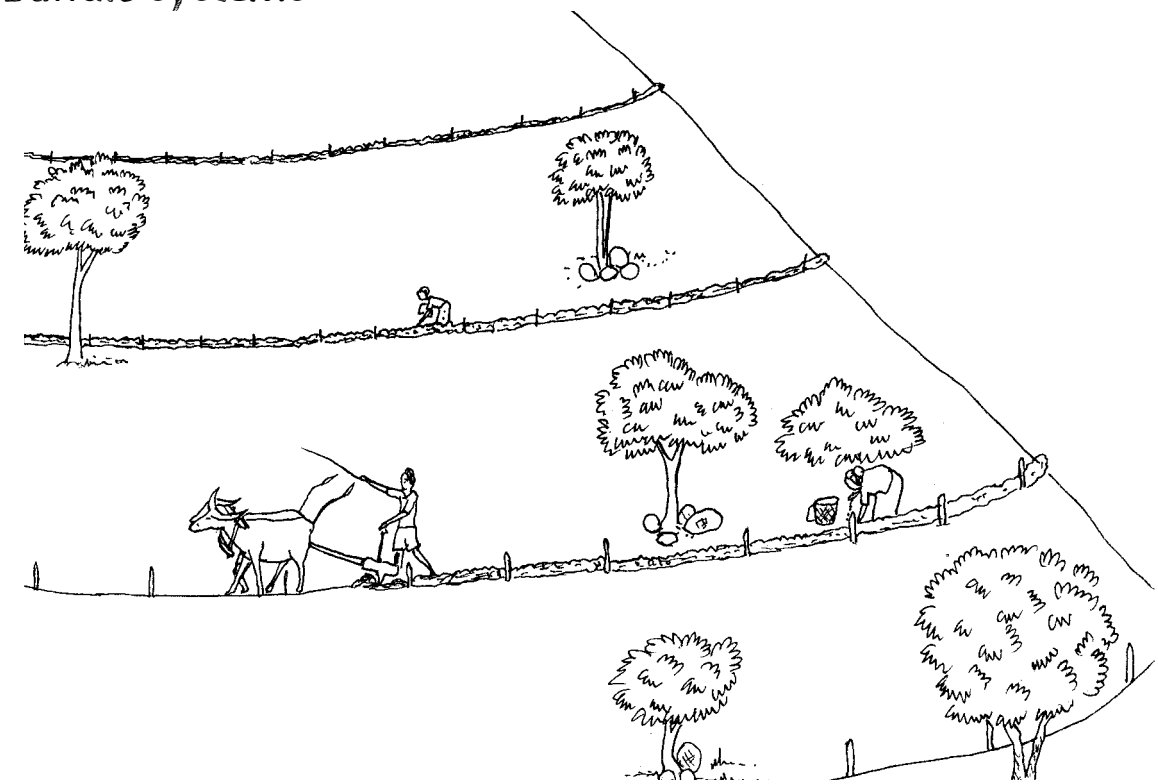
Some species of cows can be trained instead and sometimes with better results. Do some research first before you try anything.

MANURE

Buffalo provide a lot of manure, which is easier to collect if you put them in a yard at night. The manure can be:

- Put in compost or liquid compost.
- Dried and used straight on fields and paddies.
- Spread around fruit trees.
- Added to biogas systems.
- Fresh manure is also used to line dams and fish ponds to stop leaks.

Buffalo systems



Preparing contour rows for planting living terraces of legume trees

AGRO-FORESTRY, ORCHARDS AND BUFFALO INTEGRATION

The same strategies can be used for buffalo as for cows – see the cow systems section for techniques. Remember that buffalo can live in wet areas where cows cannot; this difference may direct which animals and techniques you choose.

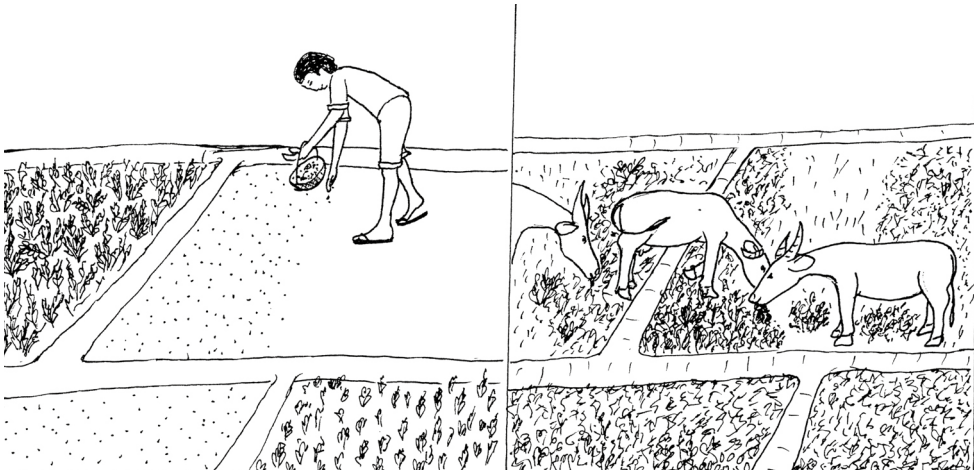
RICE PADDIES

After harvesting rice, buffalo can move onto the paddies to eat the rice straw and weeds, and provide manure for the next crop. It is best to restrict their movements with ropes tied to sticks so you can change their position around the paddies.

CROP ROTATION IN RICE PADDIES

If there is water available, plant the paddies with native legume ground covers and beans. (Do not use poisonous beans.) Collect and spread the seeds over the rice paddies. Do **not** burn the area first. Flood the paddies once to wet the soil and start the plants growing. Flood the plants again a few weeks later if there is enough water. When the plants are about one to two months old, just starting to flower, tie the buffalo to sticks with rope to eat the legumes on the paddies. There are several benefits to this method:

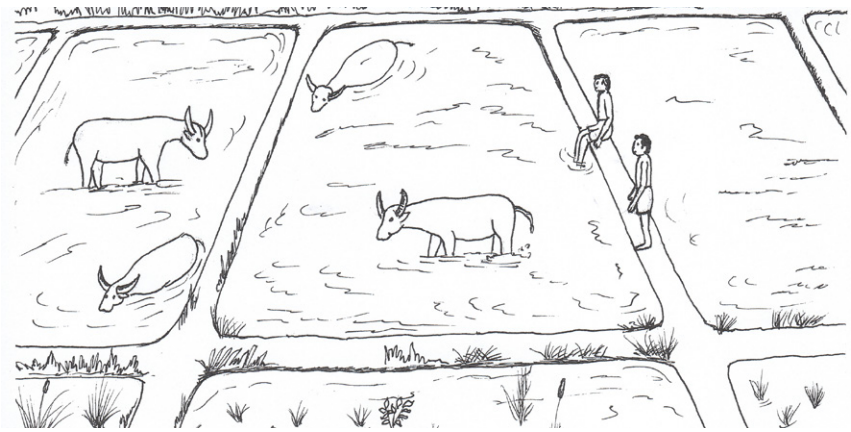
- It provides food for the buffalo.
- The legumes improve the soil in the rice paddies by providing nitrogen.
- The buffalo provide manure for the rice paddies.



RICE PADDY PREPARATION

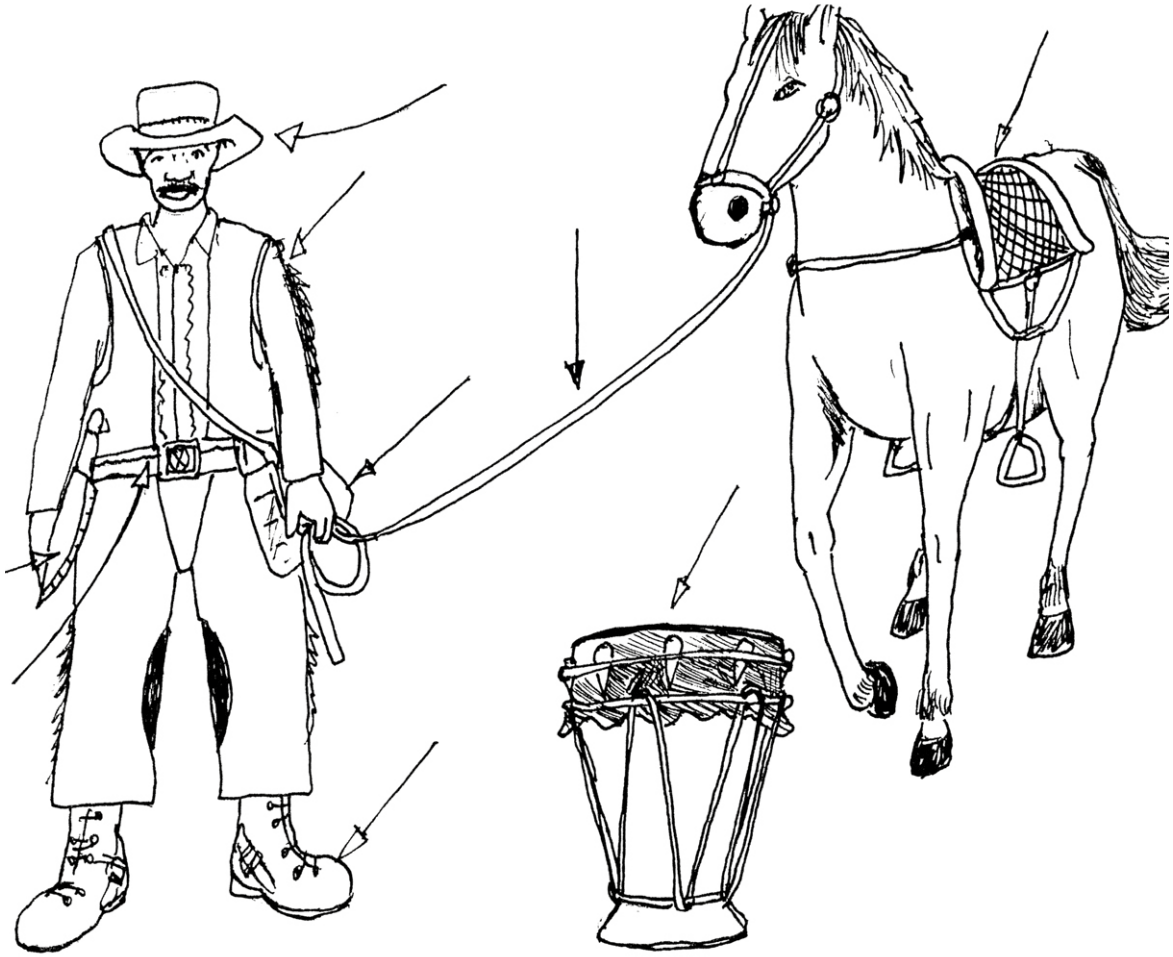
Buffalo are excellent help for preparing rice paddies before planting:

1. Allow water to flood the paddies once and leave them for a few days.
2. Bring in some buffalo and allow them to walk through the paddies. They cannot be tied to sticks but must be pre-trained and watched.
3. They turn the soil, add manure and eat the weeds or trample them into the mud.
4. After the buffalo have finished, you can level the paddies and plant the crop a week or two later.



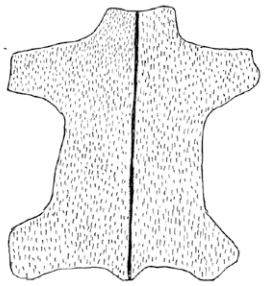
Leather

Leather is made by treating or preserving the skin of different animals. Buffalo and cows are most commonly used but goats, pigs and native deer also produce good quality leather. Each type of animal leather has different uses because of the differences in thickness, toughness and weight. Leather products include bags, belts, clothing, shoes, horse straps, machete and knife handles and machete holders.



How to make leather

Turning the animal skin into leather makes it easier to work with and it lasts much longer. The following method is simple - though there are many ways to make leather - and uses natural cheap ingredients.

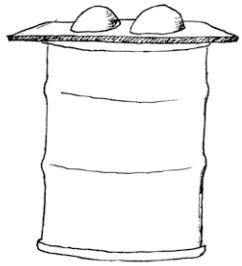


1. Soak in water

Soak the animal skin in water for two days.

2. Lime solution

The solution helps to soften and clean the skin and loosens the hair. Add 1 kilogram of lime powder for every 30 litres of water. Mix it well. Soak the skin for approximately three to four days. You can use less lime powder and leave the skin in the solution for longer. Cover the bucket or drum to protect it from animals.



2a

The skin is ready to remove if the hair pulls out easily when you rub it.

2b

3. Wash

After all the hair is removed wash the skin well with water to remove the lime solution.

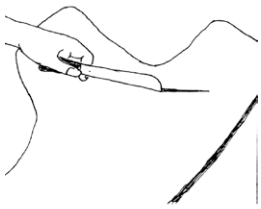
4. Tannin solution

Tannin is a natural chemical that comes from many plants. Use the bark from casuarina, neem, cashew, Indian jujube, eucalyptus, acacia and melaleuca trees to get tannin for treating the skins. Otherwise ask local experts about which local trees to use. You can also put old tea leaves in the solution to add more tannin. The tannin preserves and protects the skin, making it last much longer.

4a

Make two different solutions. The first solution uses 1 kilogram of tree bark or leaves for every 5 litres of water. Soak the skin for two to three days. The second solution uses 1 kilogram of bark for every 10 litres of water. Soak the skin for approximately 12 days until the colour is fully changed.

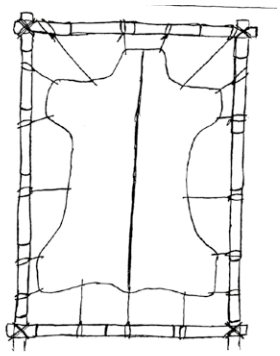
To check when the skin is ready, make a cut in it 3cm from the edge. If the skin is the same colour all the way through, it is ready. You can use less bark or leaves and leave the skin soaking for longer, or use more and soak it for less time.



4b

5. Dry and oil

Wash the skin well with water and hang it up to dry. Stretch the skin on rope between wooden poles to improve the smoothness and quality. Do not let the skin dry out completely. When it is almost dry, place the skin on a flat surface and rub oil on it. Start from the centre and rub outwards. Then hang it up again – once it is dry, you have made leather!



5

Small animals

Rabbits

Rabbits grow quickly and are a good source of meat and income. Rabbit systems take some time and labour to set up but are fairly easy to maintain. Importantly, rabbits can eat all locally grown food. They live in small houses but must also have an area where they can graze and dig – this is essential!

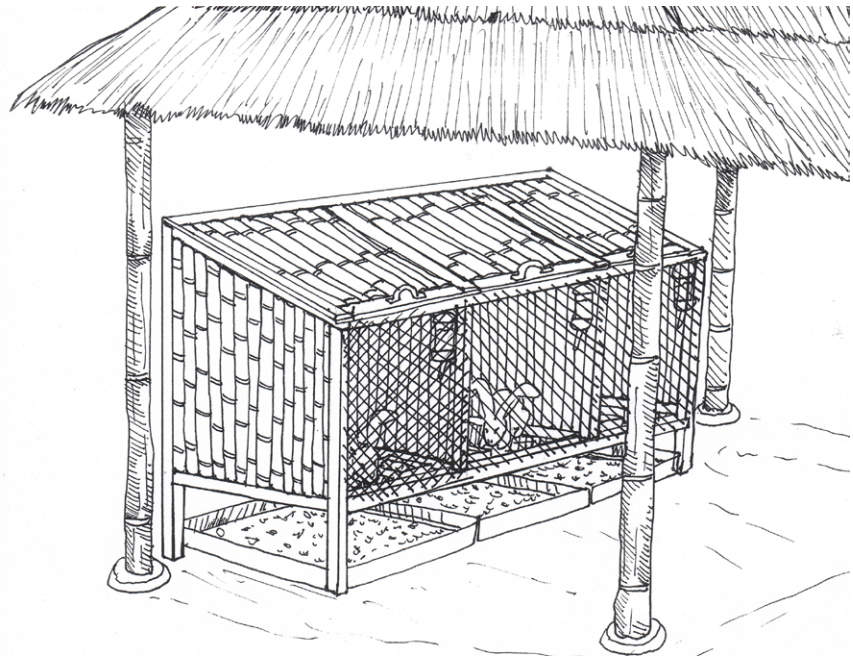
Other small animals, such as guinea pigs, have similar habits and needs to rabbits; so much of this information can be used for them as well.

Be careful: Rabbits might not cope with wet coastal tropical regions because of the heat and higher chances of sickness.

RABBIT HOUSES

Rabbit houses must always be dry because rabbits need to stay dry. It is common to keep many small houses under a large structure with a roof. Some important ideas for a good house are:

- Wood or bamboo frames and wire mesh are best but, as most rabbits will try to eat the frames, they **must** be protected with wire.
- The houses can be built just using wire, if it is strong enough.
- Always have the houses raised off the ground.
- The bottom of the house must be wire, so their manure and urine can fall straight through, and always have a system to collect and use it.
- Keep the houses as dark as possible because rabbits naturally like to live in holes.
- We consider that the official sizes recommended on the internet are too small for good health and animal rights. 60cm x 60cm x 60cm gives the rabbits enough space to move around, to stand up and to do other rabbit activities.



FOOD

Rabbits need a variety of food every day. A large handful of grains or fermented feed mix, two large handfuls of greens and some straw or dried grass are enough to keep them happy. Giving them time to graze out on the grass each day allows them to fulfill any extra food needs. They always need a supply of water in their house; half a coconut shell is a good water bowl.

Grains

Rabbits like corn and rice but soaked first in water. Rice straw is also great food and reduces the amount of corn and rice used.

Greens

- All greens should be picked one day, and fed to the rabbits the next day to help prevent digestion problems.
- The best greens are: moringa, sweet leaf, sweet potato leaf, cassava leaf (but not much and not every day), Ceylon spinach, pigeon pea, most weeds, bean and pea leaves, grass, Brazilian spinach, and banana leaves.

Fermented feed mix

If you make the mix, only feed the rabbits a small amount of grains but the same amount of greens.

To prepare the mix you need:

- 50cm long piece of banana stalk finely chopped
- A quarter of a big bucket of weeds, finely chopped
- A quarter of a bucket of rice powder (the powder from the rice de-husking process)
- Mix the ingredients together in a large bin. Add 500ml of water and a quarter of a cup of micro-organism activator (read Soil **Ch 9**).
- Leave the mixture to ferment for two days and feed it to the rabbits.

This recipe is for about 20 rabbits, and will be used before the food ferments too much. To make the mix for more rabbits increase the volume of the recipe ingredients.

Straw or dried grass

Rabbits need a regular supply of straw or dried grass to eat as they need it.

SMART IDEA:

Build a rain-protected rabbit house above compost bays. With a wire mesh floor the manure and urine fall through straight onto the compost heap!

Feeding ideas:

- The food **must** be kept separate from rabbit urine and manure, either in a separate raised container or section in the cage. Put food on top of the house if the rabbits can reach it and it is made from wire.
- In the wet season harvest the food as early in the day as possible, so it dries before the rains come.

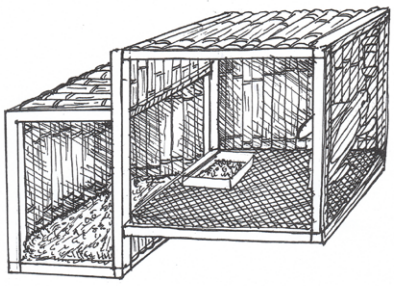
BREEDING

Rabbits breed often and produce a lot of babies or kits. The most important factor for breeding is to allow the right rabbits to breed at the right time. Planned breeding:

- Choses only the best mothers.
- Prevents inbreeding.
- Allows you to limit the number of babies to the number of houses.
- Reduces the food needed.
- Improves your stock.

Breeding ideas to improve the success rate:

- Females and males **must** be over five months old before mating.
- Bring the female to the male's house, not the other way.
- Successful mating occurs more often during a new moon.
- Breeding requires darkness, such as a covered box on the side of a cage.
- Mating is successful if the male faints after mating! Allow him to try three times. If he tries many times without fainting, the female is not interested and it is best to separate them because it causes stress.
- To prevent inbreeding keep a record of the breeding parents and do not let brothers and sisters mate. Records of when breeding happens also lets you know when the babies are due, approximately 30 – 35 days afterwards.
- Identify the best females (those with a high mating success rate and good mothers, etc.) and keep breeding them to improve your genetic stock.
- When females start scratching out their fur, they are pregnant. The fur is to make a nest, but in the tropics rabbits do not have a lot of fur. Instead you need to add other materials for the baby's nest – cotton and kapok are good.
- Sometimes the mothers kill the first round of babies. If it happens more than once, remove that rabbit.
- Females require a little box for babies that is protected from rain and wind, lined with rice husks, cotton, kapok, etc., and changed every week. Do not touch the babies. After the second week the babies begin to eat other food. After five weeks they stop drinking milk and need to be separated from their mother. After two to three months separate them from each other to prevent inbreeding. Their box must be lower to prevent the babies crawling into the main cage.
- Feed the mothers well including more moringa leaves in their food during pregnancy and while nursing the young.



HEALTH

Important ideas for good health include:

- For healthy teeth provide fresh bamboo, sugar cane, mulberry and neem branches.
- Rabbits cannot get wet or be in contact with their manure and urine.
- Do not let them get too stressed.
- Keeping track of their weight is a good way to know if they are sick – if their weight drops they are probably sick. Other signs are eating less and diarrhoea.

MEDICINE

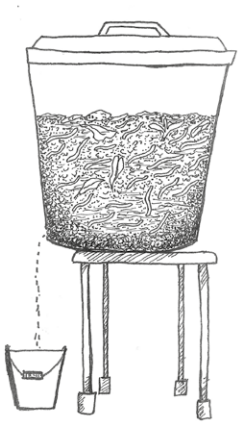
- Aloe vera is good for healing wounds.
- Neem leaves are a good supplement in rabbit food but, similar to the animals previously mentioned, too many cause health problems. Neem powder is good if they do not eat leaves – three leaves or half a teaspoon per week with their food.
- Guava leaves.
- Papaya leaves but not papaya fruit or seeds.
- Seaweed once per week supplements their vitamin and mineral intake.
- Feeding and grazing space.
- Rabbits need space to graze and dig. Make a living fence, grown with various rabbit foods, for the poles, attach 50cm high wire to keep them in. 5m x 5m for 20 rabbits is a good size.
- Be careful which rabbits you let out – they are likely to mate if given the opportunity. One yard divided into a few securely sectioned areas helps to prevent unplanned breeding.
- Never leave them out at night because of predators.

PRODUCTS

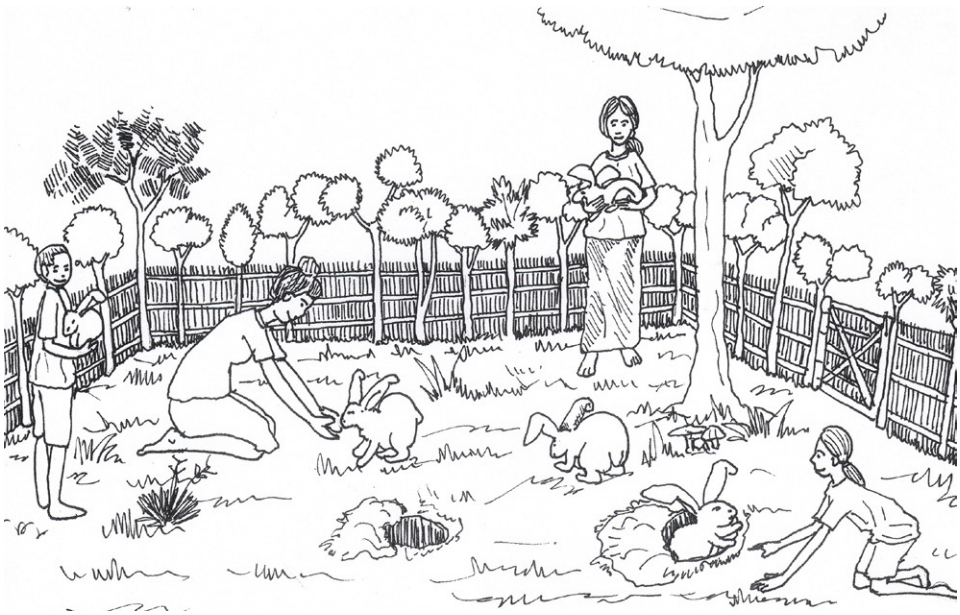
Rabbit meat: If rabbits are well looked after, they can grow to 2.5kg by six months, which becomes half that weight after the meat is prepared and ready to eat. The meat provides food or income.

Rabbit manure and urine can be used in many ways:It makes great worm food – add it to worm farms to maximise the benefits and fertilise a large area

- Add it to compost heaps.
- Add it to fishponds to increase fish food production - as the manure decomposes algae and plankton grow, which is eaten by most fresh water fish species.



Worm farm for turning rabbit manure into high quality compost



Rabbits are great for eating your weeds and are good pets for children.

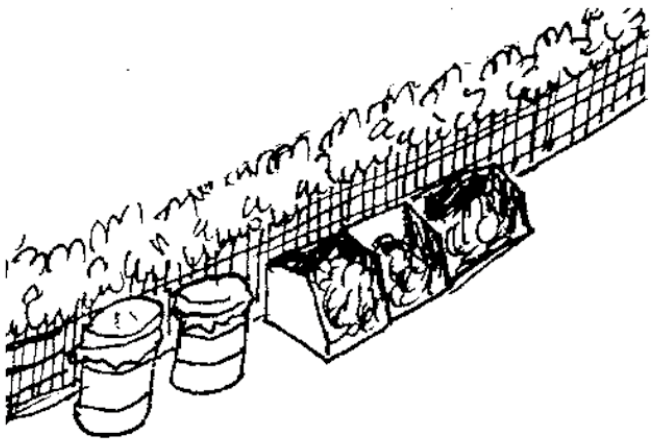
Pigeons

Pigeons are easy to keep and breed, and are a good source of meat.

Place pigeon houses close to the house; they need protection from predators and rats.

Their house can be made cheaply from mostly local materials. Pigeons find most of their own food but it is important to feed them some extra grains, such as broken rice or crushed corn, to keep them coming back to the house. Some natural food and water sources are ponds, trees and flowers. They need a permanent supply of water.

Pigeon manure is valuable! It is strong and high in nutrients that are hard to find in other manures because pigeons have diverse food sources. Use it when making compost and liquid compost; never put it straight on your garden.

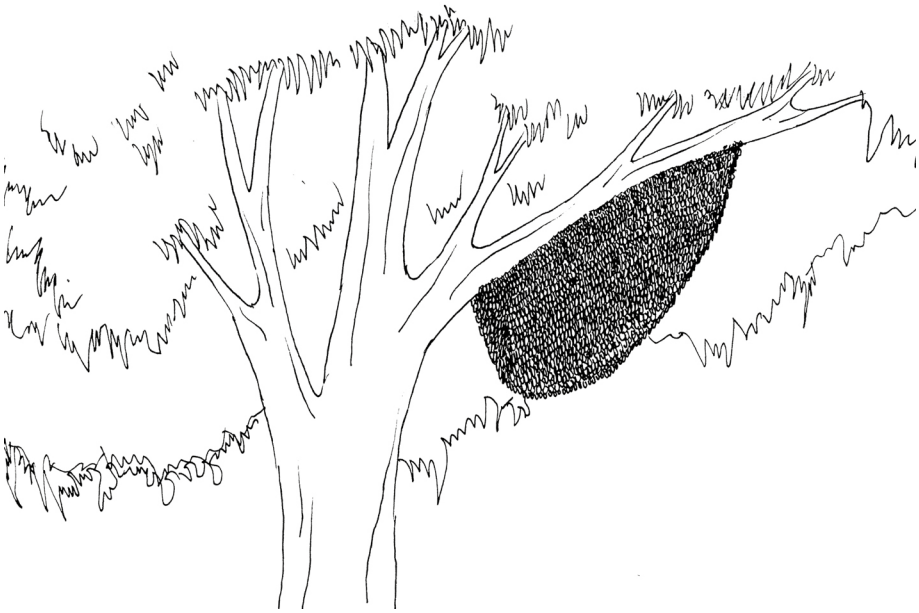


Other animals

BEES

Bees are one of the most important creatures on the planet! They are vital for the natural environment and for our food production through their pollination work, as well as providing us with valuable products, including:

- Honey for eating, providing lots of natural energy.
- Honey for income.
- Honey for health – it has natural antibiotic and anti-fungal properties, and can stop infections in cuts and sores.
- Propolis – a glue-like product bees make to seal small gaps in their hives. Dark in colour, it is a traditional .medicine for sore throats and some infections.
- Wax for candles and other products.
- Many people also eat the honeycomb with the bee eggs inside. This is also a valuable food source containing many vitamins and minerals; however, it is often fried, which destroys much of the goodness.

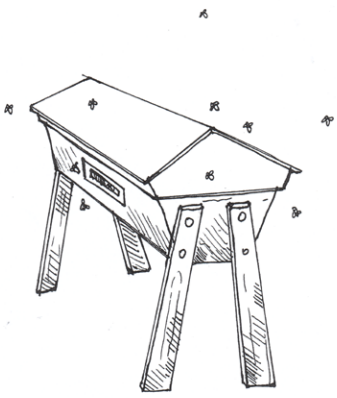


To improve pollination rates plant lots of flowers and flowering trees so bees come more regularly. Add a few rocks to one part of the pond, so the rocks touch the water surface. This prevents bees from drowning in the pond.

Bees are sensitive to their environment and, unfortunately, many agricultural practices have caused bee populations to decrease quickly. Stopping the use of chemical pesticides and herbicides would make sure we have agricultural systems that are healthy for bees, or they will not survive. This would be globally devastating to our food production and the environment.

Beehives

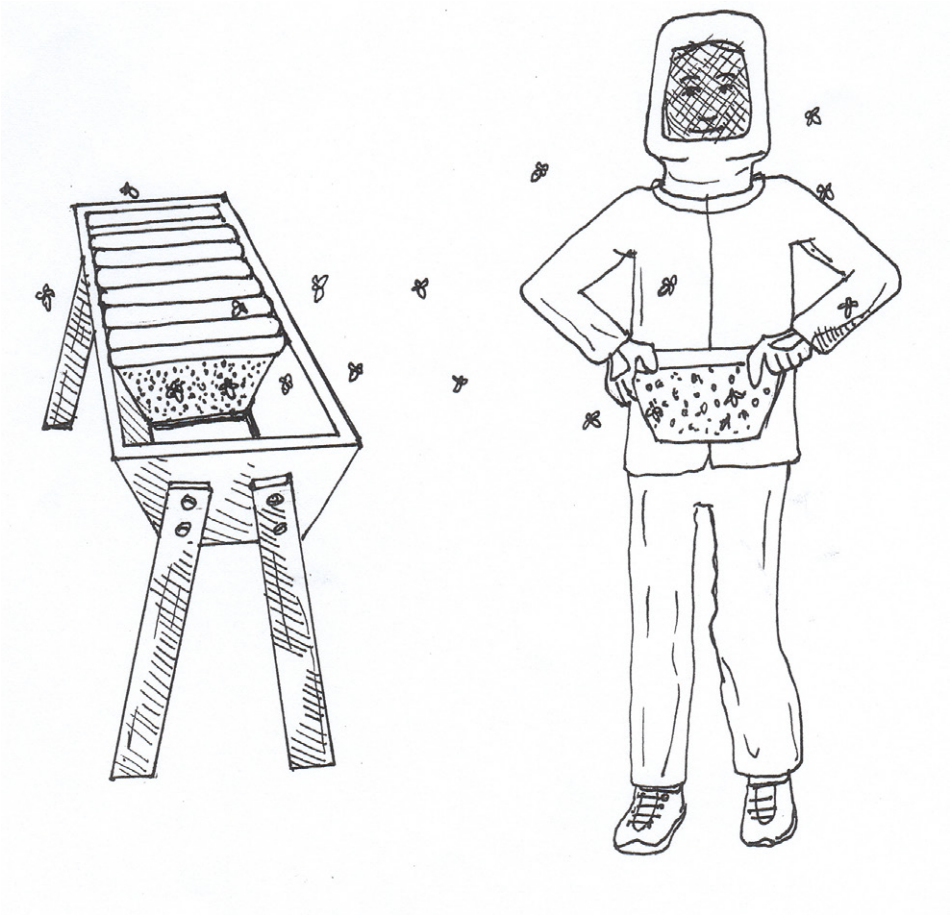
There are different types of hives for keeping bees. The oldest type – a good system for the tropics – is called the top-bar hive. It is simple and easy to build, does not need wax, and it works with native and introduced bees. You can add the bars from which the bees attach honeycomb to the hive as needed.



The basic steps are:

- **Build the beehive** – a rectangular wooden box with bars across the top, a bee entrance and a weatherproof cover.
- Seal the outside of the beehive to protect it from the weather by painting on a mixture of heated bee's wax and natural oil. The bees seal the inside of the hive themselves with beeswax and propolis.
- Collect a wild hive or bees from another hive. It is important to wear appropriate protective clothing and to know how to use smoke to quieten the bees without harming them.
- Introduce the queen bee and as many worker bees as possible.
- Add more bars as the hive expands.

Read the reference chapter for detailed information on building and managing a top-bar beehive.



An important strategy for improving honey production is to increase the food supply (flowers) near the hives:

- Create an all-year supply of flowers for regular production – it helps to create a calendar of flowering plants so you know there is a plant flowering every month.
- More flowers near the hives means more honey because the bees travel less. Bees can search up to 5km for pollen, which uses a lot of energy, so the bees then consume a lot of the honey themselves.

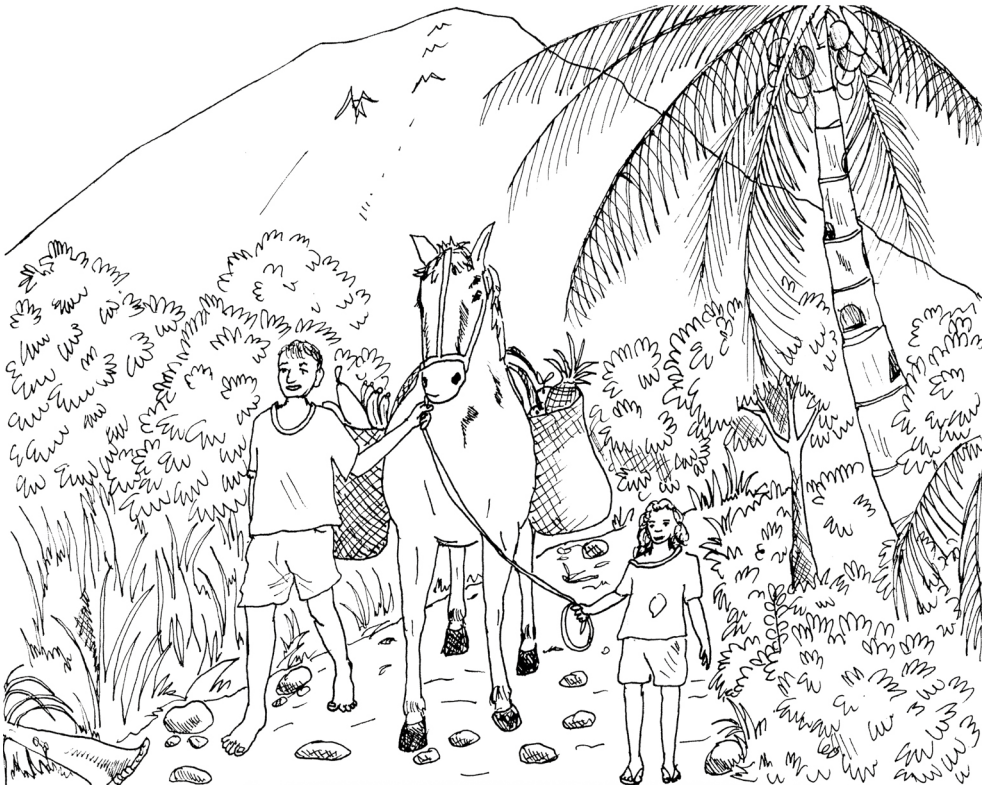
Native bee hives

In many countries, such as Timor-Leste, people collect honey from wild native bees. Beehives, such as the top-bar system, can be made for the native bees, which are then **carefully** brought from the wild and introduced to their new homes. Collecting honey is easier and more honey is produced.

Native bees and their unique tasting honey **must** be protected, especially where there are no introduced bees. Bees introduced from other countries usually bring diseases and compete with native bees for food.

HORSES AND PONIES

Horses and ponies are still common in many tropical countries. In some areas of Timor-Leste their ponies are unique and important to Timorese people for transport, trading and for the economy, especially in the mountainous areas.



Treat your horses and ponies well and they will return the service:

- Provide good quality grass, legume leaves and other food to eat, and water every day.
- Use old clothing or padding to prevent the ropes from cutting their skin.
- Treat any cuts or sores quickly to prevent infections and worms. Aloe vera and other traditional medicines help.
- Feed them mulberry bark and green papaya seeds sometimes (once every two to three months) to help prevent worm problems.
- Provide them with some sea salt regularly for their health.
- Lemongrass is an excellent treat for horses and can even be used as a training device for a reward.
- Bamboo leaves are good stock food for horses.
- Add some neem leaves to their diets occasionally.

It is very important to plant many trees to provide horse food, medicine, shade and fencing. By growing what you need for your animals you create a sustainable and low-cost system.

DOGS

Dogs are a common animal in tropical countries. Dogs are loyal animals, good companions and can be trained to catch rats and mice, to guard against thieves and to prevent animals from eating your crops. They behave much better if they are trained and, if they are also fed and treated well, they are more loyal, protective, work hard, and are much happier and healthier.

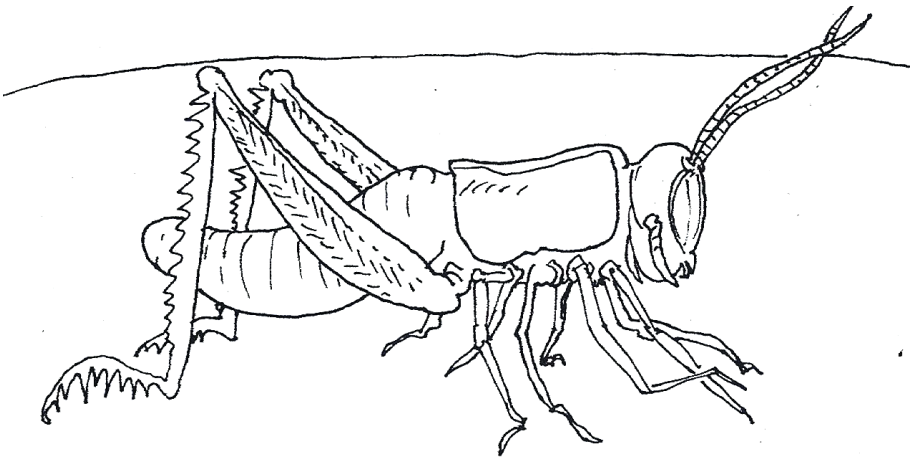
In some countries dogs control and move sheep and cows from field to field, and are much better at it than humans!

Some simple ideas for raising dogs:

- Let the puppies stay with their mother until they are six weeks old. This ensures they are healthier, will grow bigger and are less susceptible to disease.
- Dogs love any scrap food – fish, meat, rice, some vegetables – and it helps their health and their size.
- Add green papaya seeds to their food sometimes to help control worms. Add neem seeds or a few drops of neem oil to their food occasionally for better health and to reduce parasite and worm problems.
- Aloe vera, coconut oil and neem oil are good for treating mange, a skin disease caused by the build-up of microscopic mites.

INSECTS

In many countries people regularly eat insects and even produce them for food. They are the most efficient way to provide a high level of protein, using much less water and food than any other animal! As the world's population continues to grow, insect production will become more common.



Working together with communities

Working together with neighbours and communities makes animal management easier and cheaper. It improves the wealth and health of the whole community.

Working together already happens a lot, such as maintaining land to feed animals, and there are many ways to improve animal management by communal work.

Animal health

Disease prevention through good animal health and clean animal houses/yards is most important. However, when diseases do occur, it is important to work with government agricultural workers and the community to prevent diseases from spreading.

This involves:

- Identifying the disease as soon as possible.
- Separating diseased animals from healthy animals to stop infection.
- Treating the disease quickly and effectively.

Use traditional medicine if appropriate, but if you need to buy medicine, it is cheaper to do in a community group.

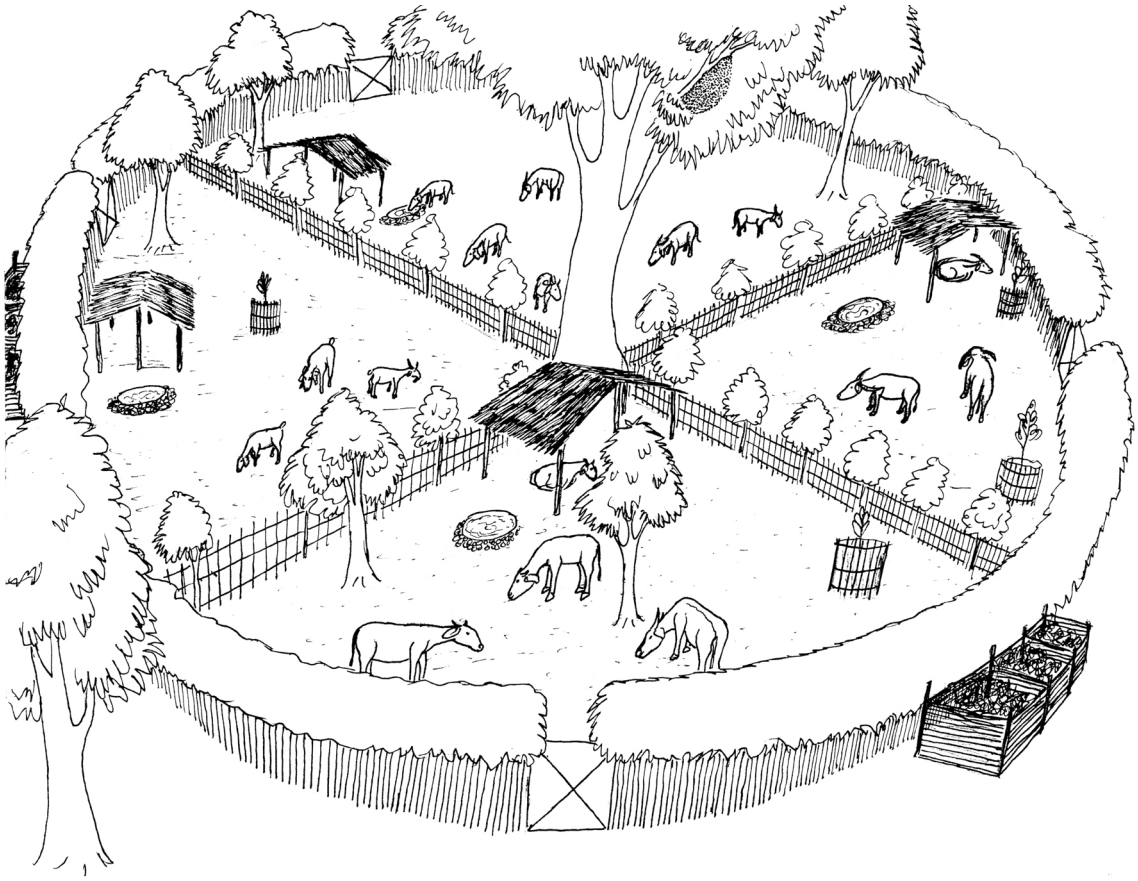
Take care not to spread diseases within a community and from one community to another.

Some animal diseases can be prevented by vaccination: For example, Newcastle's disease for chickens, anthrax for pigs. It is the same as when children are vaccinated against tuberculosis and measles. All the animals in a community MUST be vaccinated at the same time for disease prevention to work properly. It is much easier to organise vaccinations through community groups or local NGOs than by individuals.

Community animal breeding

It is important to use the healthiest males for breeding, choosing the animals – the bulls, for example – from a community to breed with the cows. Choose more than one male to prevent inbreeding, and regularly introduce new healthy bulls from outside your stock into your breeding program. This produces healthier calves and improves the quality and health of all the animals.

A breeding system can work when a community group buys some breeding animals. The community group looks after the animals and the families in the group divide the young between them.



Example 1: A community group buys three pigs – one male and two females. One family in the group keeps and feeds the pigs. When the females have piglets, they become the property of the family. When the young pigs are old enough, the three original pigs are given to another family in the group. And so on.

Example 2: A community group buys three female ducks and one male duck. The group builds a duck house and yard, dividing the work and duck care between the group members. When ducklings are born they are shared between the group members to keep for themselves. Alternatively, the young and eggs stay in the community duck house, and the group sells or eats the extra ducks and eggs.

These are only two examples: There are many ways to organise an 'animal bank'. It is important to plan before starting, and appointing a record keeper helps to reduce any potential problems.

For example, think about and plan for:

- What happens if the animals get sick or die?
- Are there rules for taking care of the animals to prevent sickness?
- How are the young animals divided between the families?
- Does each family or the community group supply the feed?
- Who does the work and supplies the building materials?

Another option is for people to join together to buy young animals. For example, five people each pay 20 per cent and raise the animals either to sell or to eat. They then each receive 20 per cent of the money from selling the fully grown animal or 20 per cent of the meat. The people can either share the time and resources to raise the animal or one person receives more for looking after it. This needs to be agreed beforehand.

Cooperatives are a great way to maximise the benefits and reduce the costs of raising animals, especially for larger animals. Read more in the Cooperatives chapter (**Ch 5**).

Community land for feeding animals

When community land is used for feeding animals, it reduces labour time and shares resources - water supply, improving grazing, food quality and fencing.

Here are some factors for increasing the benefit of feeding on community land:

- Move the animals regularly to prevent over-grazing.
- Work out a sharing system to manage costs and labour such as legume ground cover seeds, making fertiliser, building and repairing fences, etc.
- Mix tree crops with grazing land, which improves animal production if managed well. Take care not to let the animals eat the young trees and crops.

For small animals:

- Collecting market waste is a great way to supplement animal feed, but remember not to feed too many avocado and tomato skins to chickens, as it can make them sick.

Community animal yards and houses

A community can build their animal yard or house on communal land or neighbours can share an animal house or a fenced yard. The yard is best if situated near community or shared feeding land and is under some shade trees near a good water supply. An added function of a feeding yard is to fatten animals before eating or selling them. It has many benefits:

- It takes less labour and fewer resources to build one big shelter rather than many small shelters.
- It creates lot of manure for fertiliser, trading or selling.
- Easier for providing feed and water.
- Better for market access and selling animals.

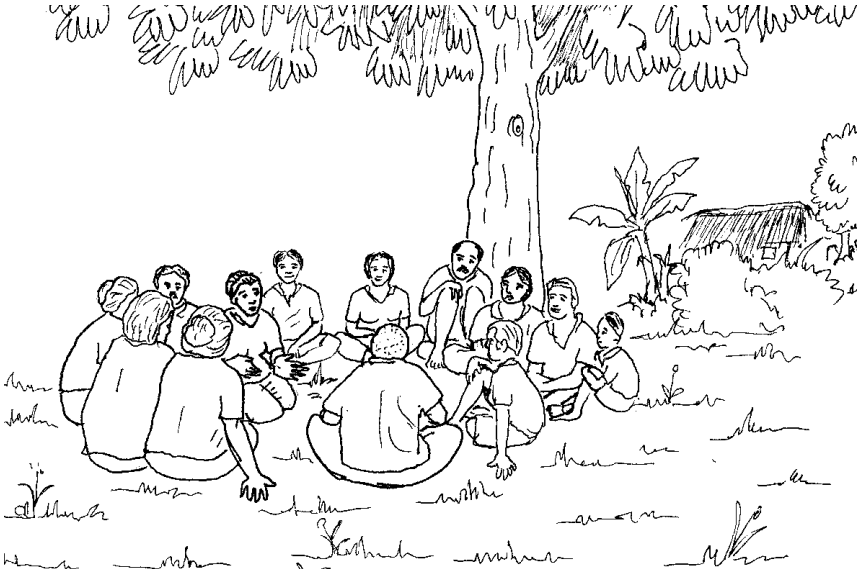
Larger animals have a more negative impact on the environment and are more expensive than smaller animals. Therefore, there are more benefits from community management plans for them than for smaller animals.

A big benefit for having community animal houses for small animals, especially chickens, is to stop them destroying people's vegetable gardens. "Wild" chickens cause a lot of damage and are hard to control when they are free but they are more easily managed in a shared animal house.

Community agreement on animal management

Animals destroy crops and small trees very quickly. The best way to prevent destruction is by working with your community to understand the problem and make an agreement. Community meetings are a good way for everyone to come together to find a solution. This includes:

- Long-term plans and design for animal feeding, crop and tree areas.
- Community and individual fences.
- Deciding where animals can and cannot feed – this changes at different times of the year.
- Introducing penalties for animals eating crops or trees.



You and your community have to decide either to fence the animals in or out of certain areas. It is best for families, the environment and the community to fence animals in, but make sure the areas are sustainable systems where animals can still graze, scratch, peck and live healthy lives. It takes more time and resources to have fenced-in systems but the production increases a lot and the returns are much more than the inputs.

Large animals still need big grazing areas, but cell grazing – where animals rotate between smaller fenced or designated areas – is a more sustainable system of land management. The many benefits are:

- Individual and community production of vegetables and fruit increases a lot when animals are fenced in, as well as allowing better animal production if they are well looked after.
- Manure becomes a valuable product for potential trade.
- Fruit trees within the animal fences produce much better.
- The soil is much healthier with an increased diversity of grasses, legumes and other plants.
- Animal health is easier to observe and maintain.
- The surrounding environment is much healthier, as rivers are less degraded; springs are protected; with less erosion and tree regeneration possible.

Land divided into sections to manage animal grazing and integrate with tree crops

Finding a balance between animal grazing and environmental protection is important and a vital part of it is fence locations. Community land protection ceremonies and agreements, such as Tara bundu in Timor-Leste, are also part of this.

Protecting land, rivers and springs from animals

The future of every country and community depends on the protection of rivers and springs, and erosion must be controlled and prevented for food and water security. As it is a family, community, regional and national concern, solutions must be found at every level.

Springs are damaged or destroyed and spring water dirtied if animals are allowed to drink directly from them.

Animals cause river damage by:

- Destroying the river edge and removing vegetation, especially cows and buffalo.
- Eating river-edge plants.
- Walking in the rivers and fouling the water.

Erosion is caused by:

- Removing too many trees from sloped land.
- Not preventing animals from overgrazing grass.
- Burning the land.
- Not protecting the soil.

Bad erosion caused by mismanagement and land clearing

Solutions — family and community

Animals need water but it is necessary to control where they drink.

SPRINGS

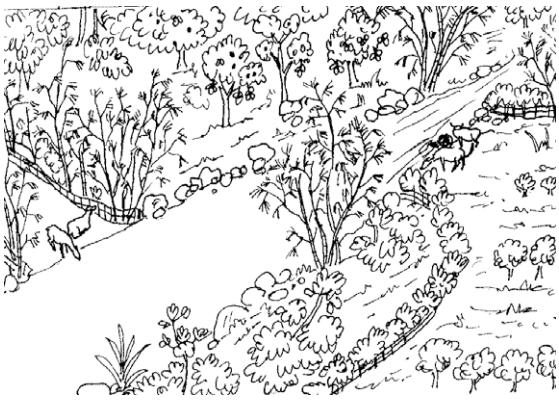
- Make a drinking water hole below the spring via a trench and build a fence around the spring to stop animals drinking from it.
- Construct a water storage tank or cemented area where the spring water comes out and use taps, pipes or overflow trenches to provide water for people and animals.

Protecting a spring and building animal drinking water holes and irrigation pipes

RIVERS

Keep and protect the vegetation on the river edge. The vegetation blocks the animals reaching the water and stops the soil from going into the river. Use fences to allow animals to drink from only a few places to keep damage minimal. In mountain areas this is very important.

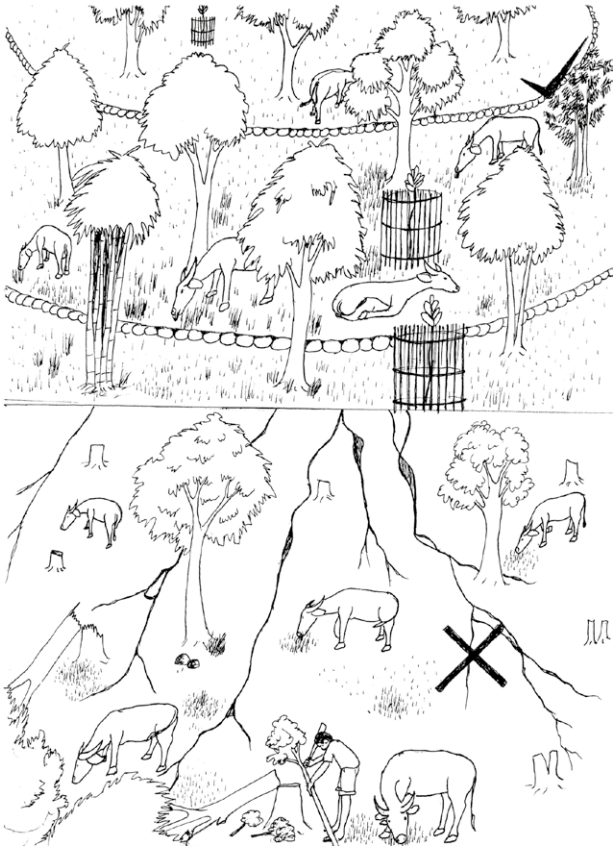
Before



After

EROSION

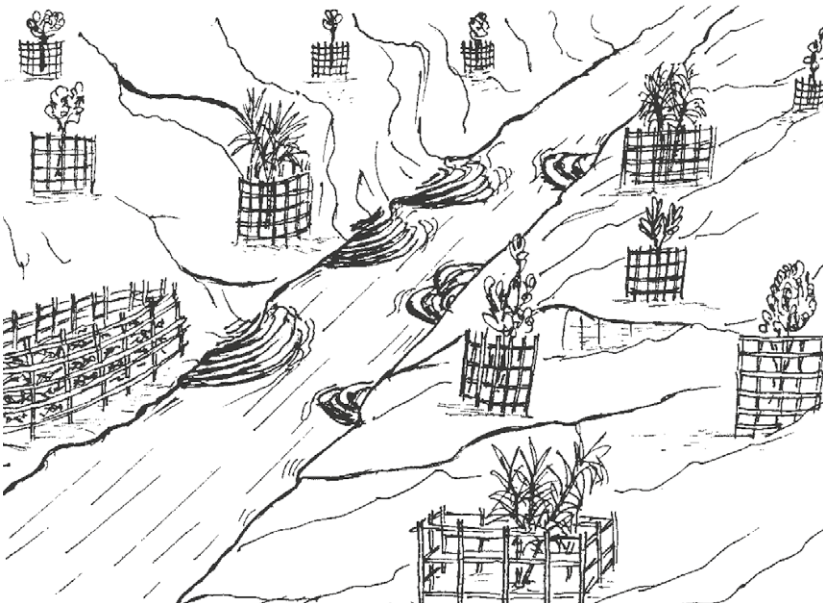
- Create swales, tree terraces or small rock mounds on the contour of the land to hold the soil and prevent erosion. Another method is to plant rows of trees to catch the soil and slowly create terraces. See Permaculture Design (**Ch 3**) for techniques.
- Leave some large trees on animal grazing land because the roots hold the soil.
- Stop the animals from grazing the grass down to the ground, or the grass will not grow back. Move them to a new area before they eat all the grass so the grass can re-grow, preventing erosion.
- Stop burning the land!

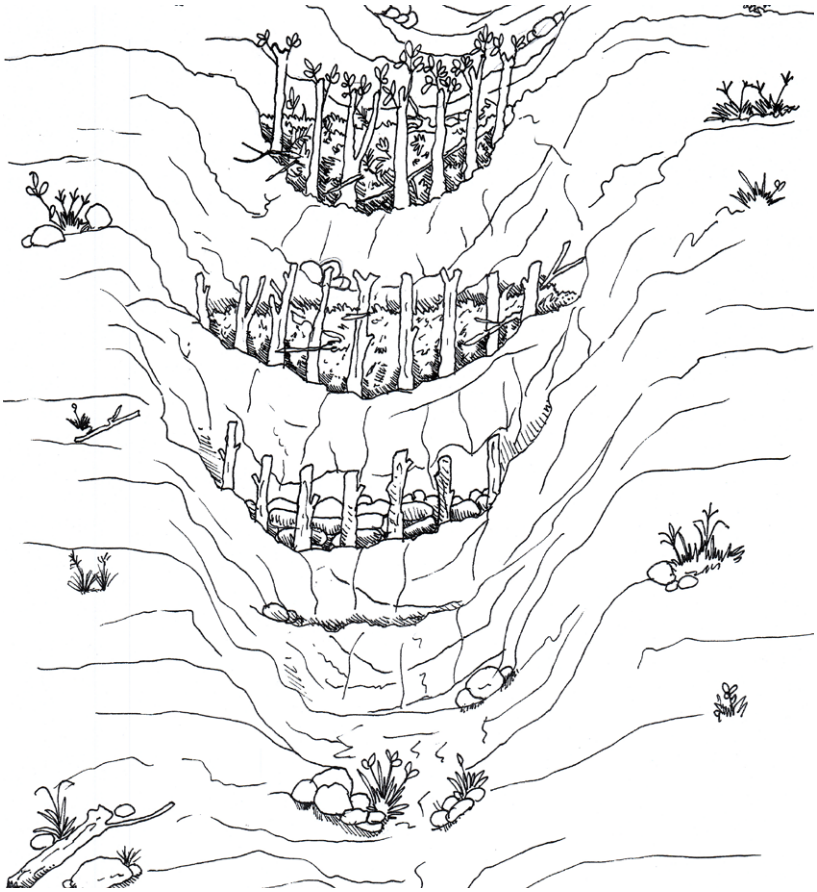


REGIONAL AND NATIONAL

Regional and national governments and international NGOs can work together with local NGOs and community groups to:

- Identify needs such as spring protection or erosion and mudslide prevention.
- Make a long-term plan to solve the problem.
- Apply step-by-step solutions.
- Educate communities in the importance of land and water protection.



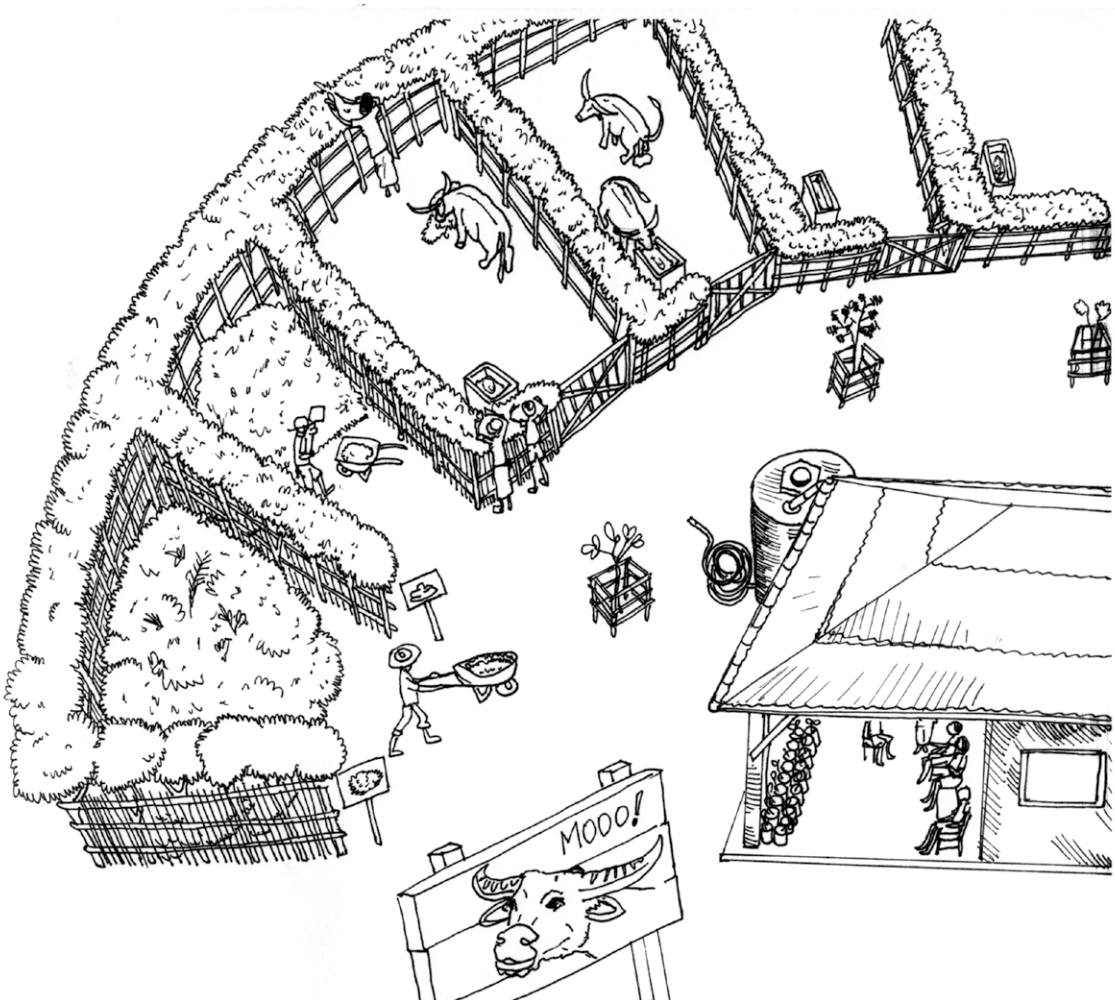


Repairing eroded and badly managed land

Market access

In communities people can easily trade or sell animals; however, market access is an essential part of animal production to increase income. If people want to sell their animals in the regional towns or large cities, transport and a good holding/selling yard are important. The farmers keep their animals there until they sell them. Many different issues must be addressed when setting up a holding/selling yard, including:

- Who looks after the animals and how much do they get paid?
- **Manure:** compost making and selling manure and compost help pay for transport or animal feed.
- **Diseases:** controls and preventative measures reduce chances of diseases starting or spreading. Medicine occasionally might be needed.
- **Animal shelters:** building, materials and maintenance.
- **Animal feed and water**: supply and costs.
- **Market days:** how often, who manages the markets?
- **Transport:** to and from the markets.
- **Animal prices:** how are they set, will the sale price also cover the costs involved in selling the animal?



Community holding and sales yard

Animal rights

Animals are living beings that deserve respect, the same as people.

It takes a change of mentality and no more effort to treat animals kindly than badly. Animals react to kindness or cruelty in the same way as humans do, and this directly affects their health and behaviour.

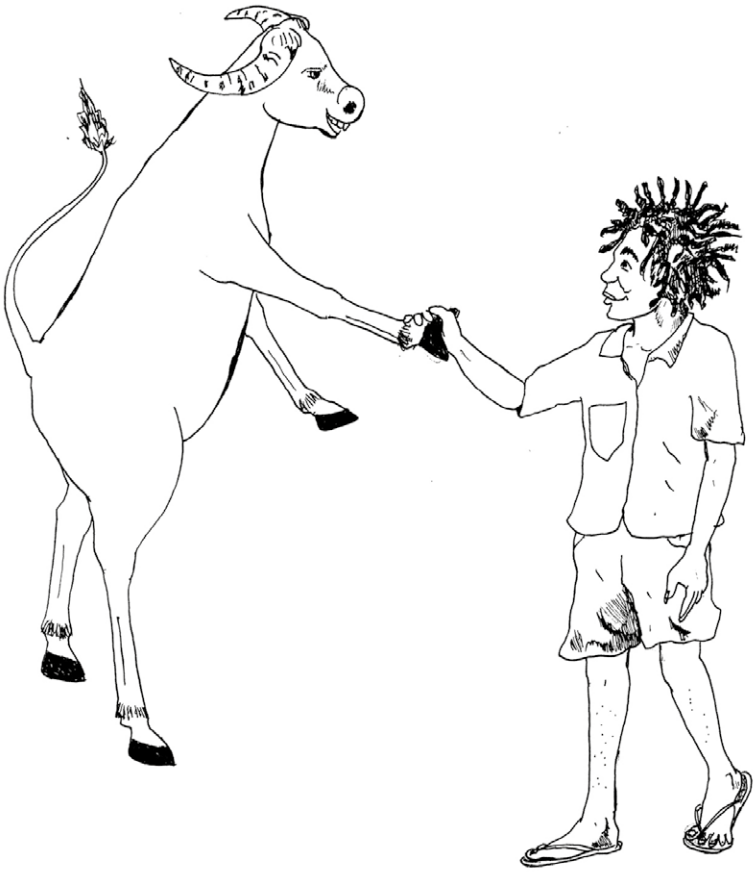
Violence and cruelty towards animals is completely unnecessary and only leads to scared, unhappy and unproductive animals. Killing animals slowly and painfully is very cruel, disgusting and disrespectful! If they are killed slowly they are also stressed. Contrary to some beliefs, stress makes the meat much tougher and less tasty.

It is also important to look after animals well because you get many benefits in return. If they are badly cared for and unhappy, it makes them less productive, less healthy and they provide less meat.

If animals are well-looked after, they are:

- Happy.
- More productive.
- Healthier.
- Bigger so have more meat.
- Longer lived.
- More fertile so have more and healthier babies.

A happy animal is a productive animal!



ANIMALS
CHAPTER NOTES

13. AQUACULTURE

18. AQUACULTURE

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Aquaculture or aquafarming is any type of water, pond or wetland environment which grows or farms aquatic animals (e.g. fish, eels, crayfish, prawns, etc.) and plants. An aquaculture system provides more produce for the same area of land than any animal farming method. It is the most efficient way to develop high quality meat with lots of protein, fats and oils. Even a small pond provides enough fish to improve diets and health significantly, especially for children.

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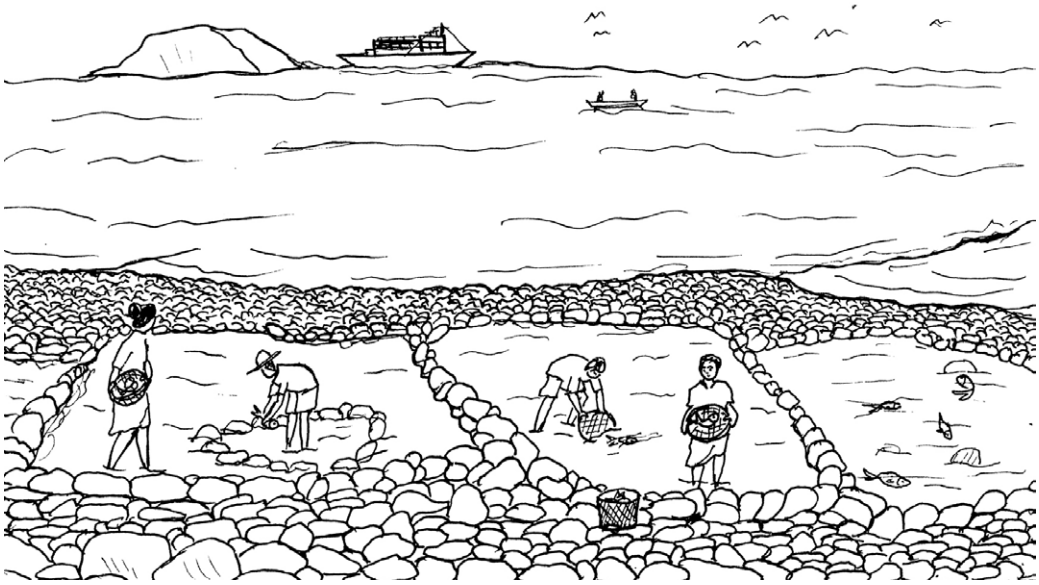
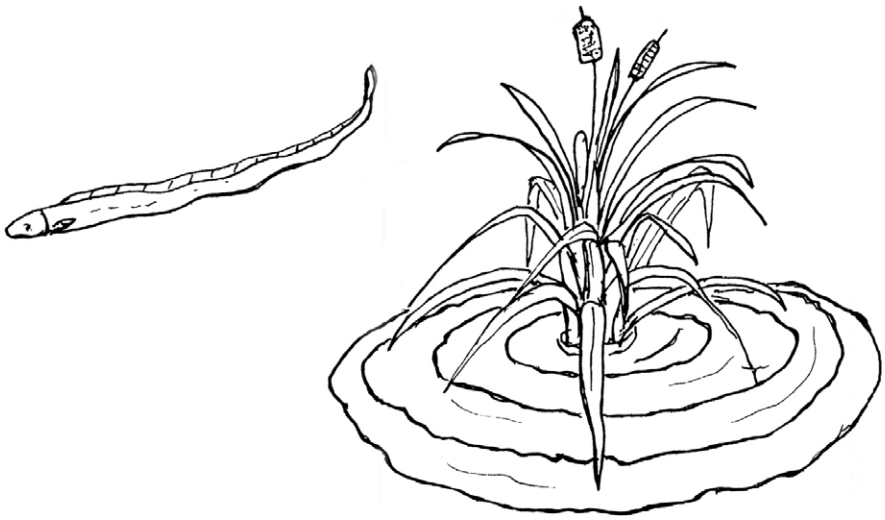
Many tropical countries are very reliant on the sea and its resources. Fishing, including trapping fish in rock pools, is part of tradition and culture. Fish is an important part of the diet and a good source of income.



Fresh-water aquaculture (fishponds) is also an important traditional practice. Fishponds provide fresh fish, and other products for food and income:

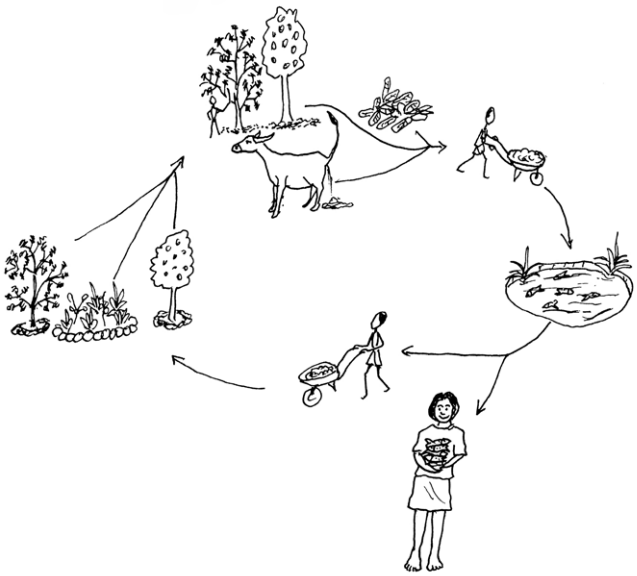
- People raise fish, prawns, mussels and eels for eating or selling.
- Water spinach, watercress, taro, bulrushes, lotus and duckweed are some of the many food plants.
- Bamboo, fruit trees, vegetables and other plants grow around the edges of fishponds.

Looking after fish is only one part of a healthy aquaculture system. There are many other factors that help to keep the system healthy and productive. Plants, insects, bacteria, algae, plankton (microscopic organisms), trees and other animals all have essential roles.

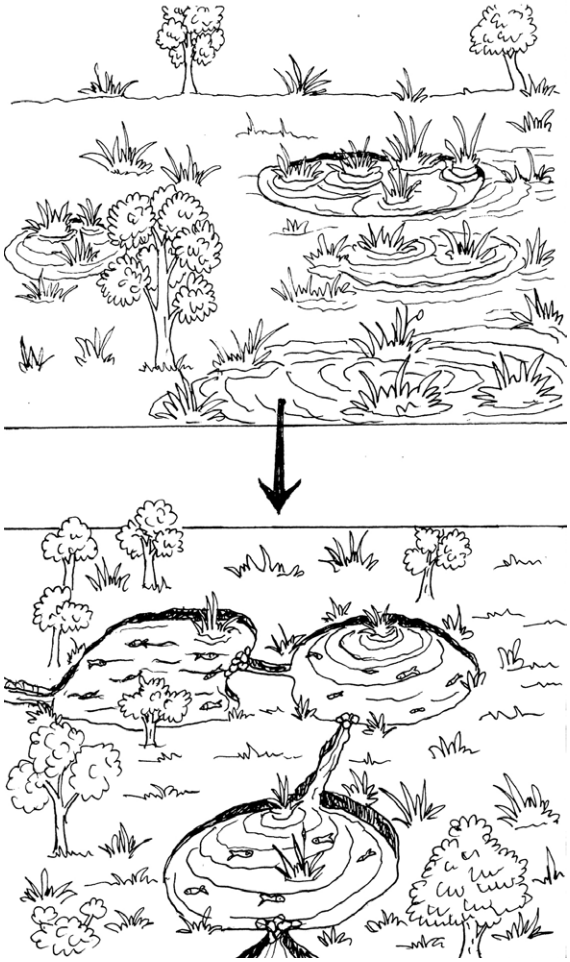


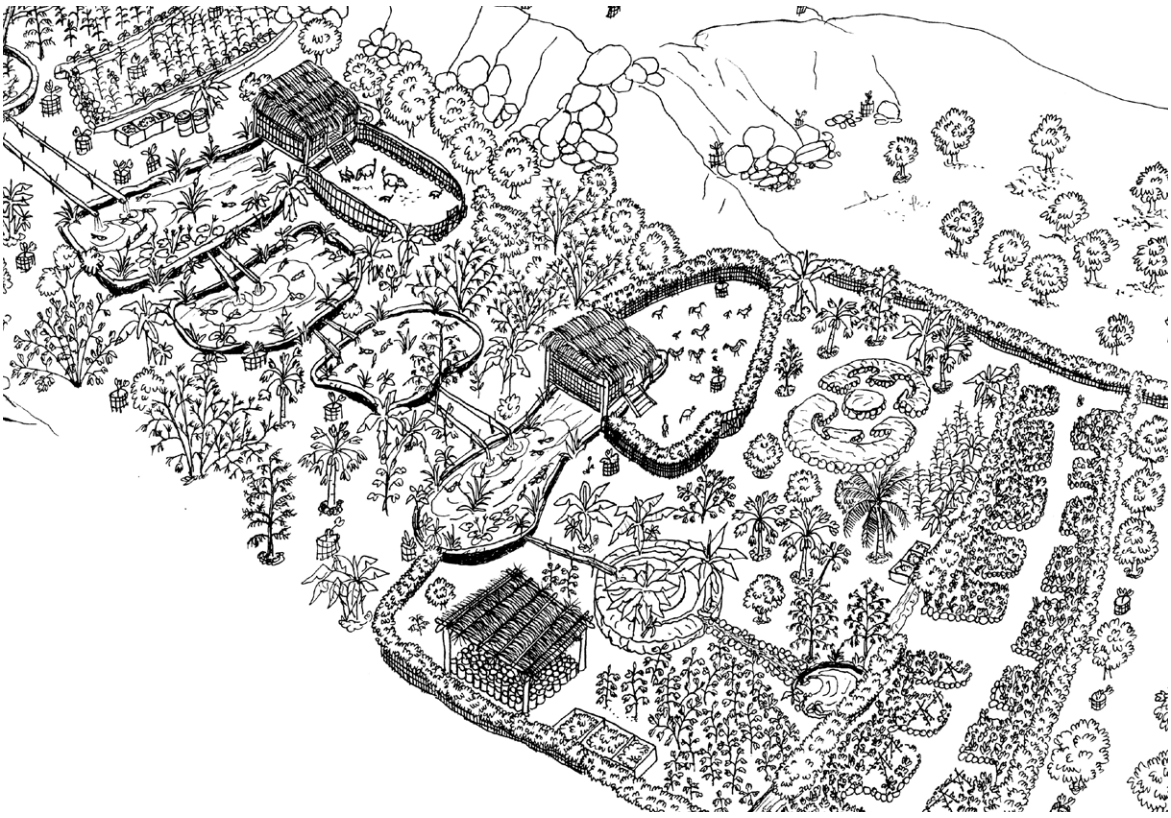
Why is aquaculture important?

1. Aquaculture is a reliable income source for families and communities, especially in remote mountain areas. Ponds have a constant supply of water so are more stable than other systems, which may become too wet or too dry.
2. People can eat the meat fresh, as it is needed. They can also trade, sell or dry the fish for later use.
3. Fish bones are also a good source of sodium, calcium and phosphorus; dried and powdered bones are an important nutritional supplement for both animals and humans.
4. Aquaculture produces many different vegetables for homes and markets, such as taro, watercress, lotus and duckweed. As nutrients are more soluble in water, they are easier for plants to absorb so their growth is faster.
5. After harvesting the fish, the ponds provide high-quality fertiliser for plants. Be careful because it is strong and very high in nitrogen. If you use it for vegetables, mix a small amount with water, the same as liquid fertiliser. Pond water is also a good low-strength fertiliser. If the ponds are close to the vegetable garden it reduces the heavy work of carrying water.
6. Aquaculture systems are a great way to turn animal, plant and kitchen waste into food for fish and water plants.



7. Make an aquaculture system on land that has low productivity or cannot be used for other plants and animals, especially swamp land. That way, your land's overall production, food and income improve.
8. Rice, chicken, pig and duck production are all possible combinations with aquaculture to improve output in both systems. You can integrate aquaculture with terraces, swales and other water catchments.
9. Aquaculture systems assist water flow and drainage in the wet season. In the dry season they provide a store of water that animals can drink.
10. Ponds provide homes, food and water for many pest predators which control pests on your crops, therefore improving crop production and reducing maintenance.
11. Aquaculture systems modify and create microclimates. They make the surrounding temperature less hot or cold, therefore making it a more comfortable climate. In colder temperatures a pond holds more heat through the night than the surrounding ground; this may prevent frost or keep the ground and the plants around the pond warmer. This is beneficial for trees and crops, and for house areas.
12. This chapter explains how to design, build and manage an aquaculture system; how to use all the extra benefits and; how to integrate it with other animal and plant production.





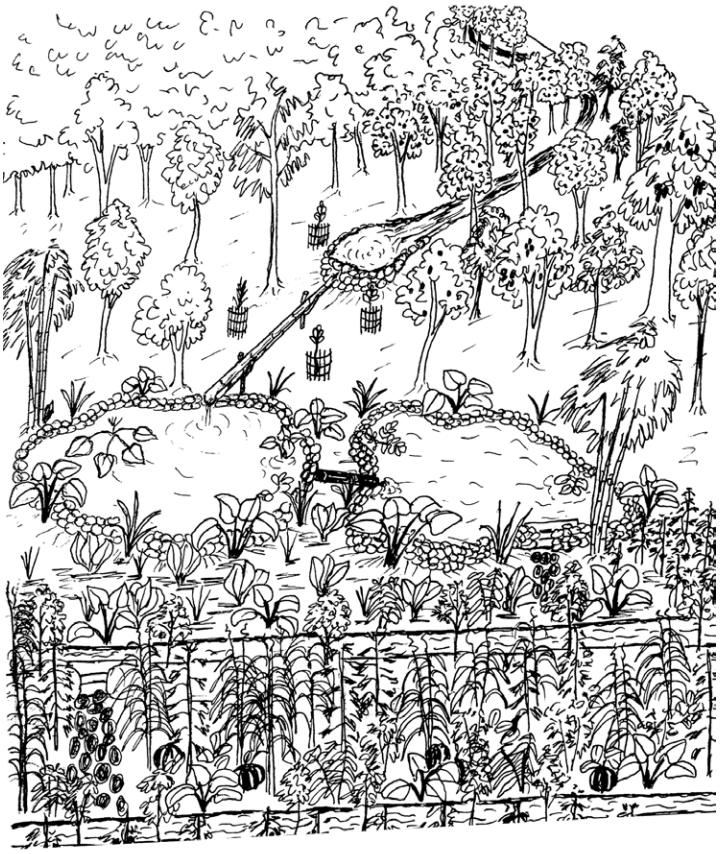
Large established aquaculture system integrated with chickens, pigs, vegetables and fruit trees

Aquaculture and the environment

Aquaculture relies on a healthy environment. If springs dry up or river flow reduces, aquaculture cannot survive. If the water source becomes dirty and polluted, so does the aquaculture system, and the fish can die. Protect your water source! This usually requires community and government engagement, and using community and traditional laws for protection.

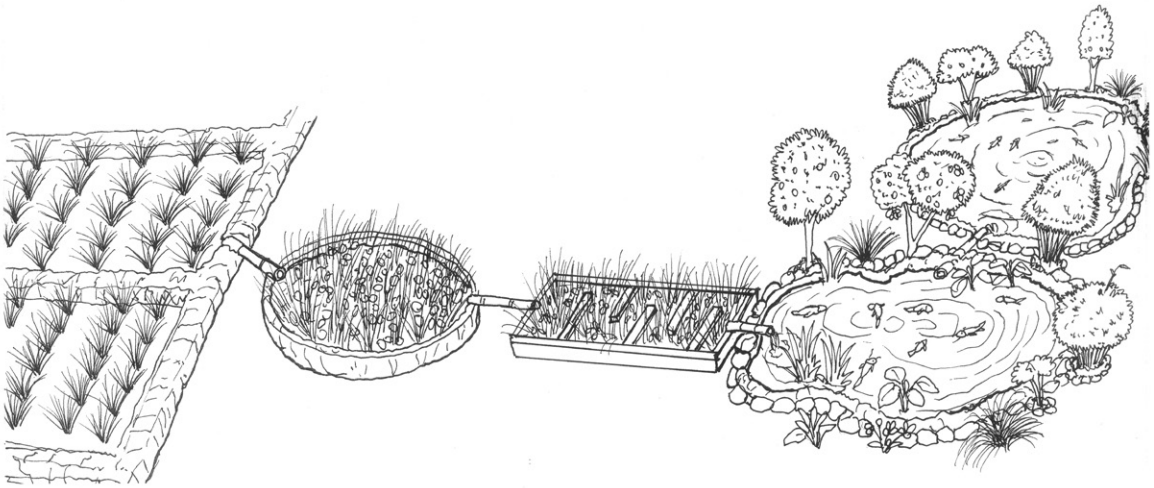
Deforestation and bad land management reduce the amount of water that enters the ground and the underground water supply. This eventually causes springs to stop running and can cause large amounts of soil and nutrients to flow into your pond or water source. This problem can be reversed, however, using swales, water catchments and reforestation to catch and store the rain water and renew underground water supplies. This also helps to maintain local biodiversity as forests protect water sources and provide habitats for birds, plants and animals.

If aquaculture water comes from rivers, communities must prevent the river from becoming dirty and polluted.



Fish become sick and die if they are exposed to chemical pesticides, and pond plants die if there is too much chemical herbicide in the water. Chemicals can enter fishponds via rivers, rice paddies and agriculture run-off in the wet season. Be very careful with the water that enters the fishponds and make sure you know where it comes from.

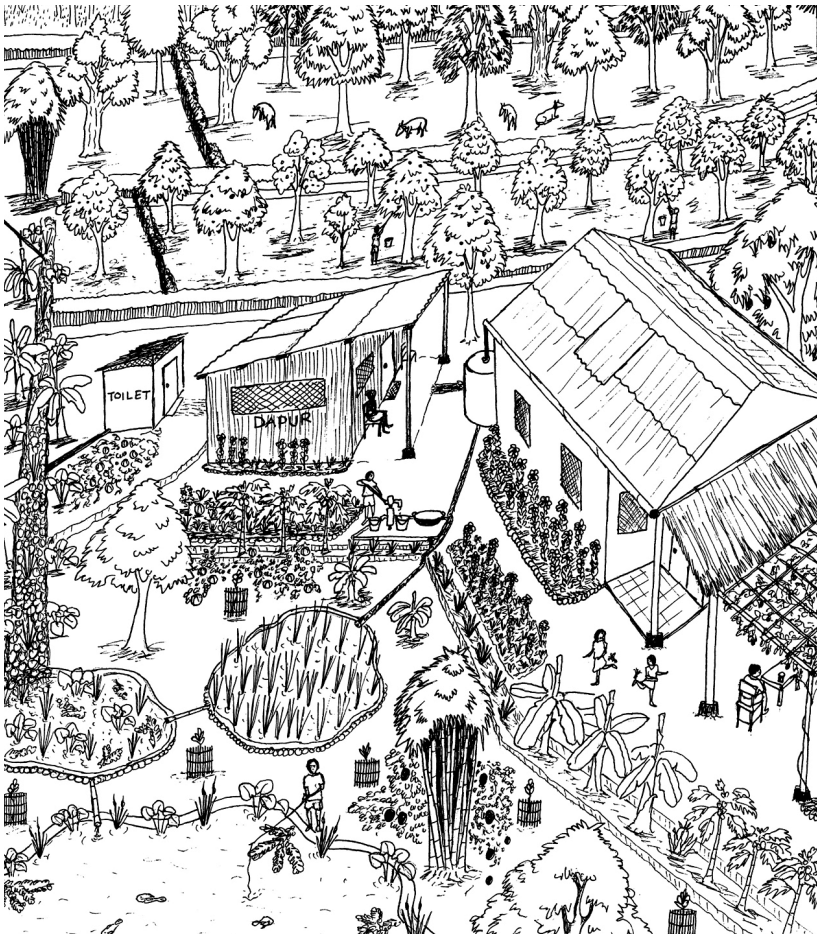
If the water is polluted with chemicals from rice paddies, rivers or house water, you can make a water-cleaning pond for all the water to go through before it enters your fishponds. These are the same as a water-cleaning ponds described in Houses, water and energy (**Ch 7**) for cleaning household waste water, also called grey-water.



Cleaning rice paddy water before it enters fishponds

Water flowing from fishponds can contain a lot of manure from fish and animals as well as plant residue. This water is great for agriculture and family gardens, but it should not enter drinking water supplies or the natural environment. It is important that bigger aquaculture ponds do not drain directly into natural rivers and streams, without first removing most of the nutrients from the water, or it creates big problems.

The excess nutrients can cause algae and plants to take over the river or stream which damages the habitat for fish and other aquatic animals. There have been many cases of thousands of fish dying when natural waterways become overfertilised by excess nutrients. Aquaculture water and sediments that contain large amounts of nutrients should always be used in other production, such as agriculture or vegetable gardens, rather than wasted or released into the environment where they cause pollution.



Collecting water from springs and houses to clean and use for aquaculture

Step-by-step aquaculture systems

You can use the strategies and techniques in this chapter to start new ponds AND to improve and expand existing ponds. An aquaculture system, whether large or small, is easier to build and maintain if the community works together.

The goal is to create self-maintaining systems that use local resources and make the most of what you have.

Thinking about water sources and slope

Objectives

- To create a pond/s that is as productive, healthy and as self-maintaining as possible
- To create ponds with as much shallow edge area or shelf as possible because more edge area equals more food equals bigger, healthier fish
- To produce different food and many products from the same area

AQUACULTURE SYSTEM NEEDS	AQUACULTURE SYSTEM PRODUCTS
Construction materials	Fish, eels, prawns
Labour	Vegetables
Clean water	Fruit
Water plants	Mulch
Land plants and trees	Better microclimate
Fish, prawns, eels	Fertiliser – liquid and solid
Fish food	Bamboo, tree products
Oxygen in the water	Income from sale of produce
Enough sun and shade	Compost materials

Location

Fishponds need a continual supply of clean water; therefore, they need to be located near:

- An irrigation channel
- A river or creek that runs all year. Be very careful not to choose a site that might become flooded in heavy rains. Use pipes, bamboo or water channels to direct water into the ponds.
- A spring
- Pumped water, house wastewater that is cleaned or any other continual unpolluted water source

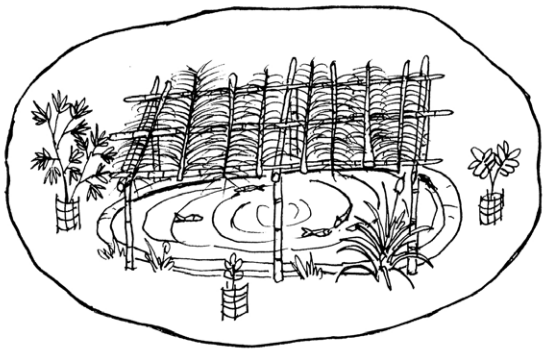
Gently sloping land makes it easier to drain and clean the fishponds and for running water into and out of the ponds. This is especially important if you want more than one aquaculture pond. Building on flat land is possible, but it requires a little more work for maintenance and water supply. Steep sloping land is more difficult to work on and requires more maintenance.

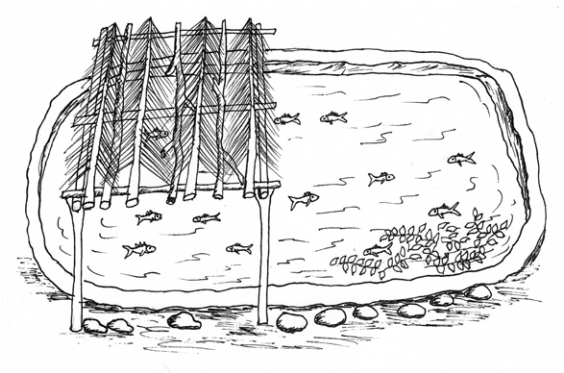
Making fishponds on floodplains is possible, but you must control the water flow, the pond edges must be above land level and the pond designs must be able to cope with extreme conditions.

Sun

For most tropical regions a small amount of shade is beneficial for the fishponds. The shade reduces the water temperature – fish do not eat or move much in hot water and may die. Cooler water holds more oxygen for the fish to breathe; as a result their activity increases which improves the growth and health of fish and other water organisms. Shade also reduces the water evaporation rate from ponds. Bigger ponds do not have as much change in water temperature as small ponds, so shade is less important.

Trees provide some shade, as do water plants that cover the surface or vines grown on trellising over the pond. Use trees that provide only light shade, provide fruit for people and fish, and that you can cut back as needed: e.g. moringa, sesbania, leucaena, panama berry, mulberry, bamboo. For small ponds, a simple shade structure of bamboo and palm leaves provides temporary shade until the trees grow taller.





Careful: Too much shade is also a problem because fishponds need direct sunlight for algae and plants to grow, and for the system to be healthy. At least half a day of direct sun is good and morning sun is the best. In cooler mountain areas where it can get cold at night, the fishponds need plenty of sun to warm the water during the day.

Size

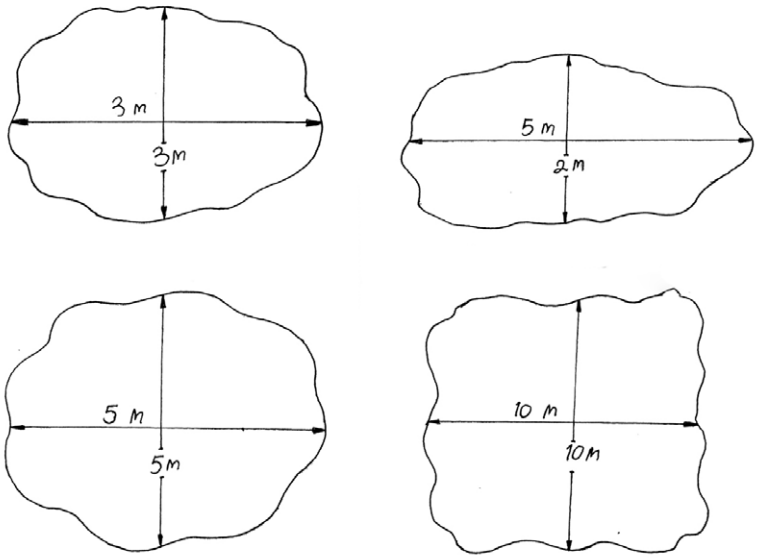
It is better to have several smaller ponds than one or two large ponds.

The size should be a minimum of 3 m x 3 m or 5 m x 2 m or 4 m in diameter. This is so the water can stay cool.

A recommended size for fishponds is approximately 5 m x 5 m (25 m^2) to 10 m x 10 m (100 m^2)

OR

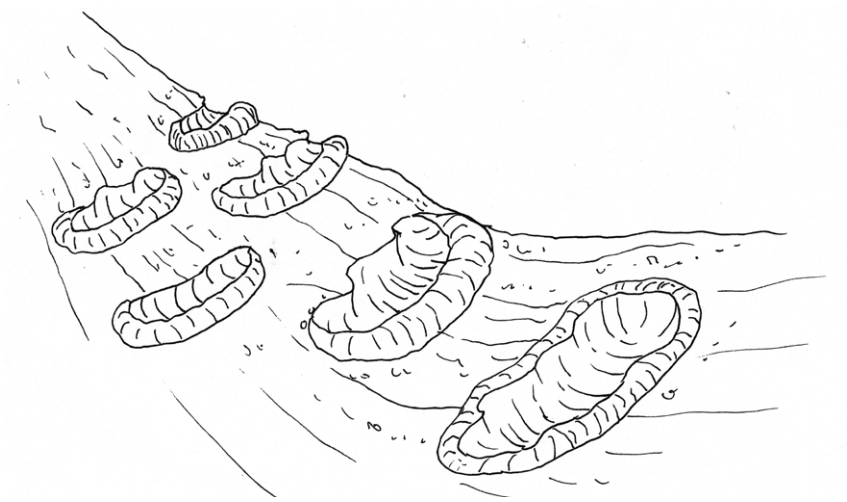
5 m in diameter (20 m^2) to 12 m in diameter (113 m^2).



However, remember, making larger fishponds means a lot more digging!

Start smaller and if the pond goes well, build another one.

- Smaller fishponds are easier to manage, clean and harvest.
- If a problem occurs in a small pond, it affects fewer fish.
- There is more shallow edge area or shelf, therefore, more food resulting in larger fish.
- You can harvest the ponds at different times.

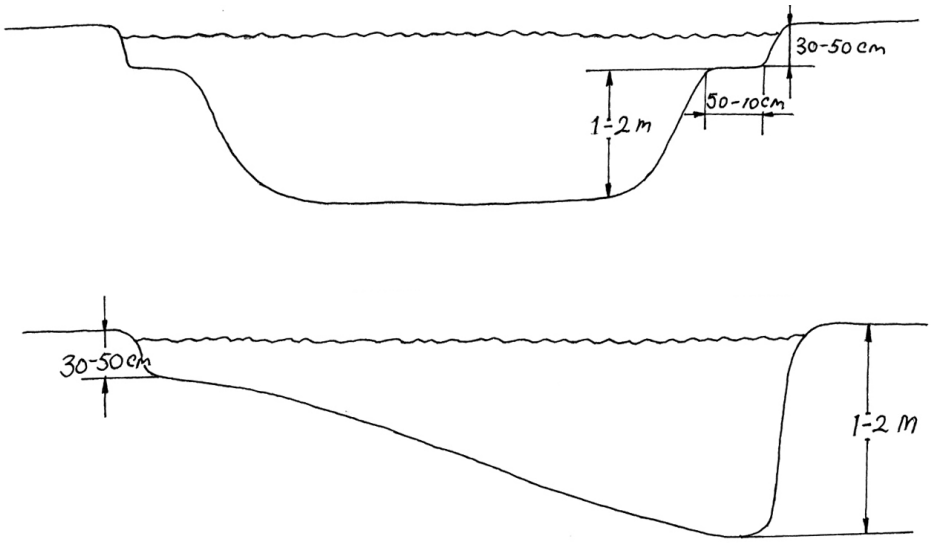


Different size and shape ponds depending on the amount of slope

Depth

Each pond needs to have a variety of depths to function properly – deeper areas for the fish when the temperature gets too hot and shallow areas for the water plants, small aquatic animals and fish breeding.

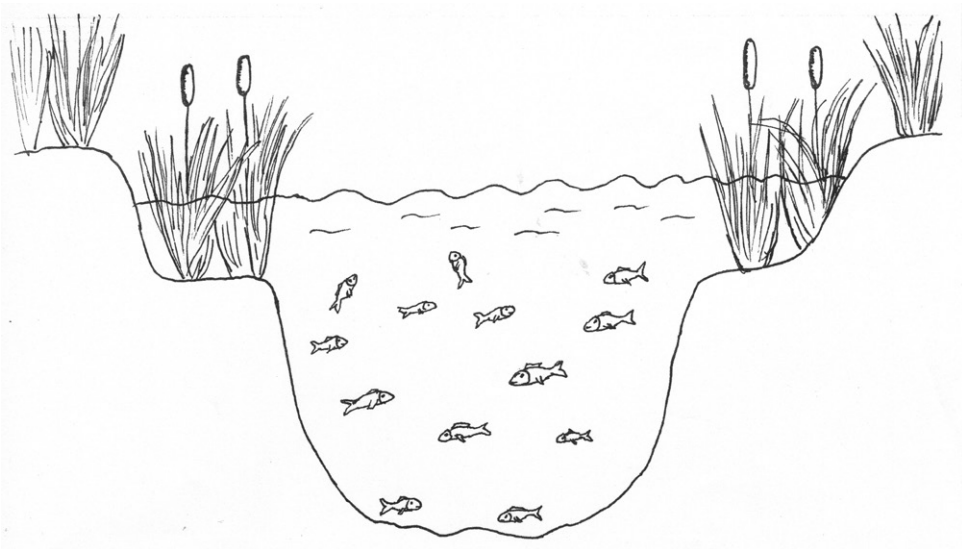
Pond design is very important. Most of the fishpond should be a minimum of one metre deep. Two metres deep is better, especially for small ponds. This gives the fish a cool place to escape on hot days. It is essential for producing fast-growing good quality fish.



Shelf

A wide shelf around the edge and a deeper section in the middle are part of an ideal design. Otherwise they can be deep at one end and shallow at the other end.

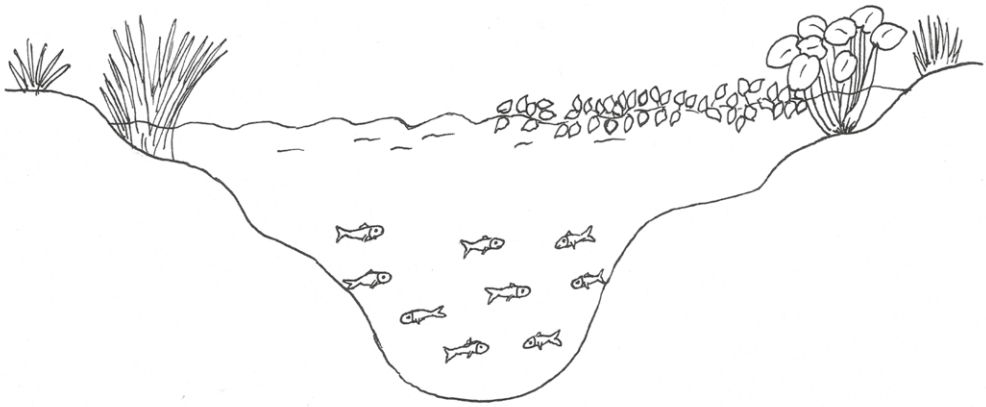
A shelf or shallow area provides a place for water plants that produce human and fish food. This area is warmer and provides a home for small fish. Shallow water and plants also promote plankton numbers, attached algae and insects, all of which are good for pond animal growth (food for fish).



Some fish, such as tilapia, need a shallow area to breed.

A good-sized shelf is about 30 to 50 cm deep and 50 to 100 cm wide.

Two shelves of different depths are even better. Shelves create edge areas in the water (more edge area equals more food equals bigger, healthier fish) and are an essential part of a self-maintaining aquaculture system.

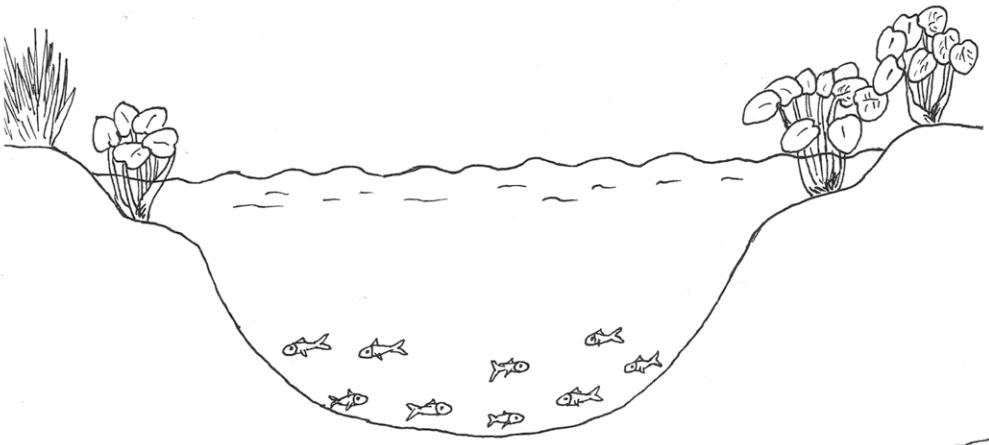


Sloping sides

Fishponds work much better when they have sloping not vertical sides:

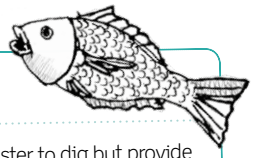
Sloping sides are more natural.

- Vertical sides are much harder and more expensive to make and maintain.
- Vertical sides create unnatural corners that fish do not like and space that fish will not use; the fish feel trapped.
- There is more space for pond animals, water plants, algae and bacteria to grow.



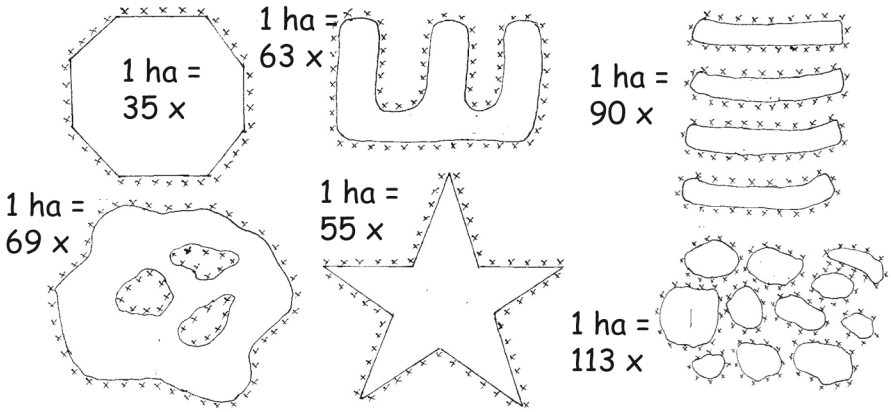
Shape

A fishpond can be whatever shape you choose to make and which suits your land. More edge around the fishponds means more area for growing water plants and fish food, and more area for growing plants and trees around the pond.



SMART IDEAS:

- Square and circle shapes are faster to dig but provide less edge area. Dig a simple shape for the deep part of the pond as it makes it easier and change the shape for the top shelf to provide more edge.
- When planning the shape of the fishponds always think of them as part of an aquaculture system that includes vegetables, fruit trees and other animals.

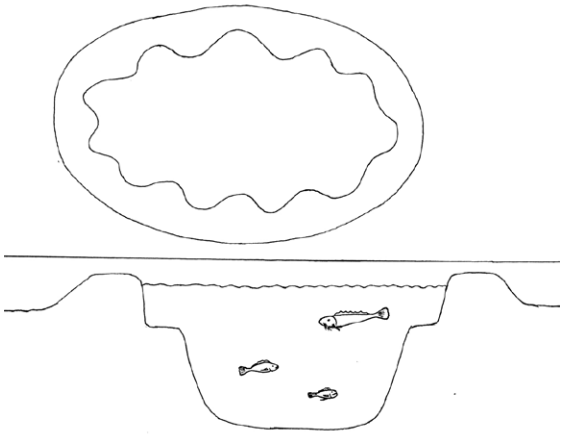


Different fishpond shapes for flat land. More edge equals more production.

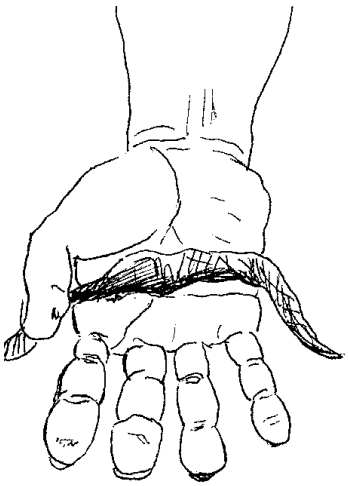
Construction

The construction of an aquaculture pond is hard work. People working together, especially when digging, make the work much easier. Remember – work smart, not hard!

- Start digging in the middle where the deepest part will be. Gradually move outwards and do not dig too deep too fast.
- Wet the ground as you go to make the soil easier to dig.
- The dug-up clay or soil that can go around the outside of the pond to raise the height of the edge. This greatly reduces the amount of digging!!!
- The extra clay or soil can create another shelf to provide more plant production areas.



Clay or cement?



Fishponds are cheaper and construction is easier if they are made from clay, but it depends if good clay is available. Many areas have excellent clay for making fishponds. A good test is to wet a handful of clay and roll it into the shape of a snake approximately 1 cm wide. If the clay sticks together, it is good to use for a fishpond.

Use clay to line the fishpond if good clay is nearby. Make a minimum 5 cm thick layer; 10 cm is much better. Be careful that the clay does not dry out in the dry season or the pond will crack and leak. It may need to be occasionally resealed with fresh clay.

Check the clay's pH using a pH meter; fishponds need the clay to be between 5 and 8. Where the clay pH is too acidic or too alkaline, use cement or pH remedies for soil such as ash or dolomite for acidic clay and sulphur for alkaline clay.

Cement is also good for constructing smaller ponds and where there is no good clay available, and it holds water better then clay.

Overall, if clay is available, clay ponds are recommended because:

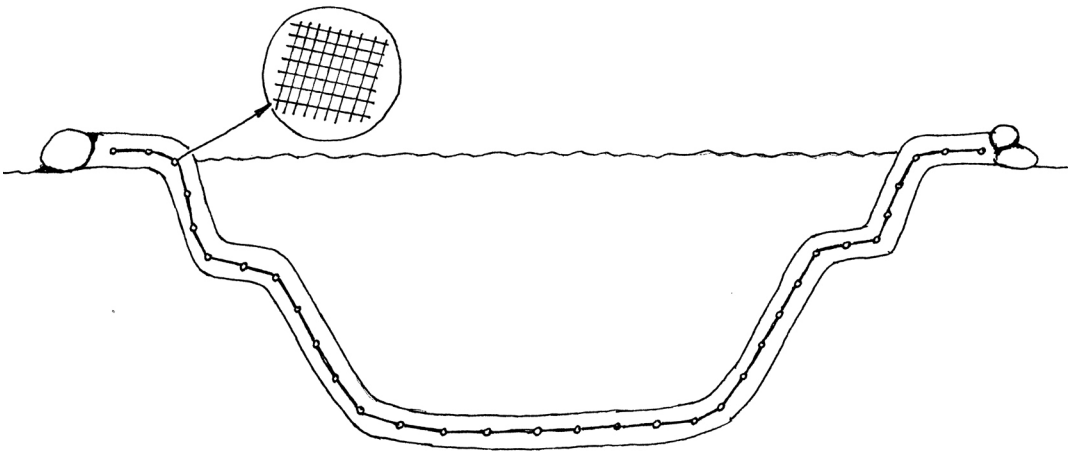
- They are much cheaper and easier to make
- It is easier to grow water plants
- There is less work providing fish food
- The nearby growing plants and trees benefit from the water and nutrients slowly leaching into the soil
- Some water from the pond recycles back into the ground to underground water supplies, which helps to keep springs flowing
- They provide a healthier environment for the fish
- The pond bottom can make good vegetable gardens in the dry season

Clay-pond techniques

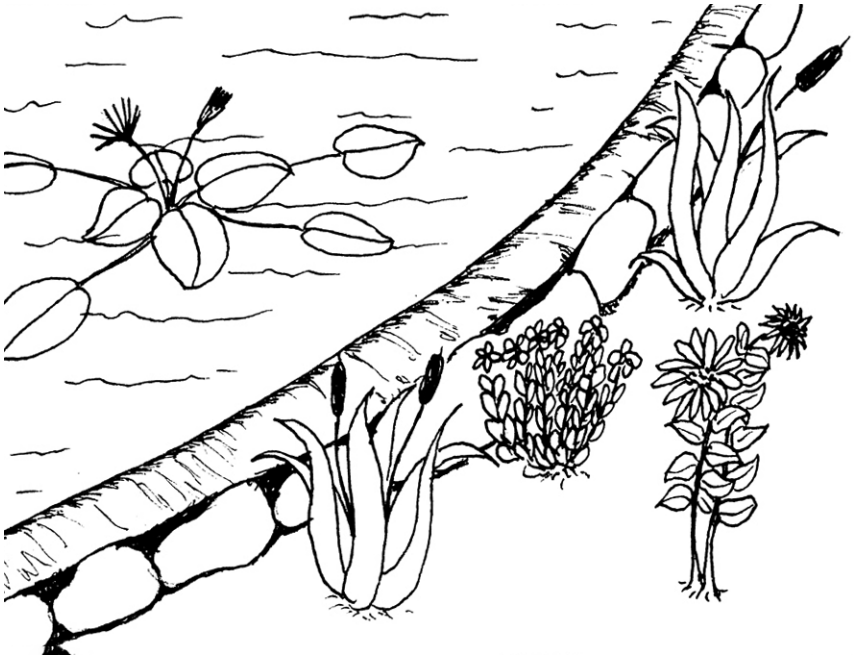
When you have made the fishpond to the desired size and shape, compact and seal the clay to reduce water leaks. This is important, especially if there is a limited water supply. A good method is to use cows, buffalo, goats or even people to walk across the bottom of the ponds and make the clay compact. Fresh cow and buffalo manure also helps to seal the pond, as does lime powder. Lime helps to balance water pH levels as well. Use 2 – 3 kg for 100 m^2 (10 m x 10 m).

Cement-pond techniques

The amount of cement used in the cement mix needs to be more than for making bricks so that the cement is stronger. It is important to use wire mesh along the bottom of the fishpond because it holds the cement together and stops it cracking. A line of rocks around the top helps the cement to hold and looks good too.



Keep the cement moist for as long as possible. If cracks appear, a final coating of cement and water painted on will seal them. Once the cement is dry, paint it with vinegar then fill it with water. Leave it for two days, then empty the water and repeat the process. Empty the pond again then fill it with water and empty it once more. This process makes the cement safe for fish.



Water for the fishponds

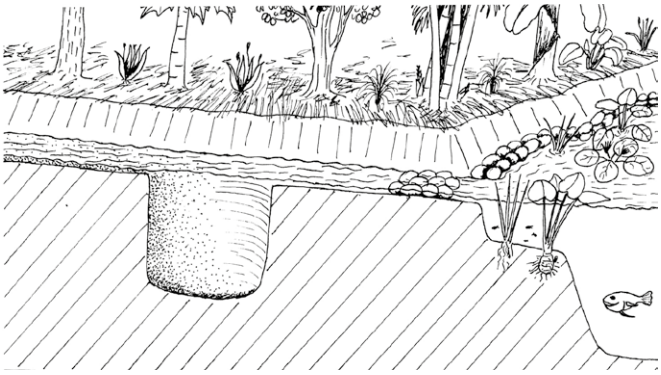
The water flowing into the fishponds must be as clean as possible to stop the fishpond from filling with soil. Water from rivers, especially, can contain a lot of soil and needs cleaning first. Too much soil creates problems with natural food production and the fishponds need cleaning much more often.

If you are going to use a water channel to collect water from a spring or a river:

- Line the channel with rocks or cement. Grasses or small shrubs planted either side of the channel help to stop erosion.
- Run the water into a pond used only for growing water vegetables. This pond catches the soil and cleans the water before it enters the fishponds. Remove the soil from this pond as needed and use it on vegetable gardens.

Water channel from spring to fishpond

Or. Dig a "soil trap" in the trench before the water enters the fishpond. Soil drops out of the water to the bottom of the soil trap as the water passes over it. Make it one metre in diameter and one metre deep if possible. Empty the soil trap whenever necessary. The collected soil is good quality and you can add it to your vegetable gardens.



A soil trap helps remove soil from water before it enters the pond

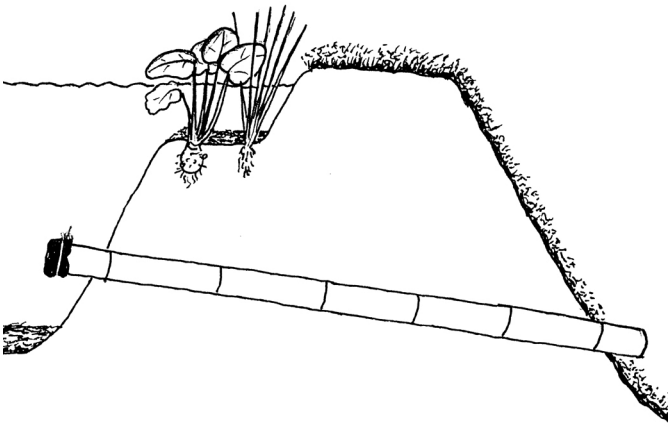
You can use a water vegetable pond or soil trap for piped water as well.

SMART IDEAS:

- If there is a good water supply, line the water channel with rocks so that some water soaks into the ground. Then plant fruit trees near the trench: e.g. coffee, citrus, pineapple, papaya. This will become a highly productive area.
- If the amount of water flowing into the fishponds is small and needs to increase, line some of or all the water channel with cement.

Drainage pipe

On sloping land, add a drainage pipe during construction. The pipe can be bamboo, plastic or metal – whatever is available. Block the end of the pipe that is in the water to prevent leaks. The pipe can empty the pond when necessary – it is much, much easier than using buckets!



You can also use a plastic hose to drain the pond. Fill it with water, place one end in the pond and the other end below pond level, keeping it closed. When you are ready, open the bottom end. The water empties through the hose using gravity. This only works on sloping land and is good for clay ponds.

Do not forget to use the nutrient-rich water as fertiliser.

Draining a pond and fertilising the garden

Water-overflow points

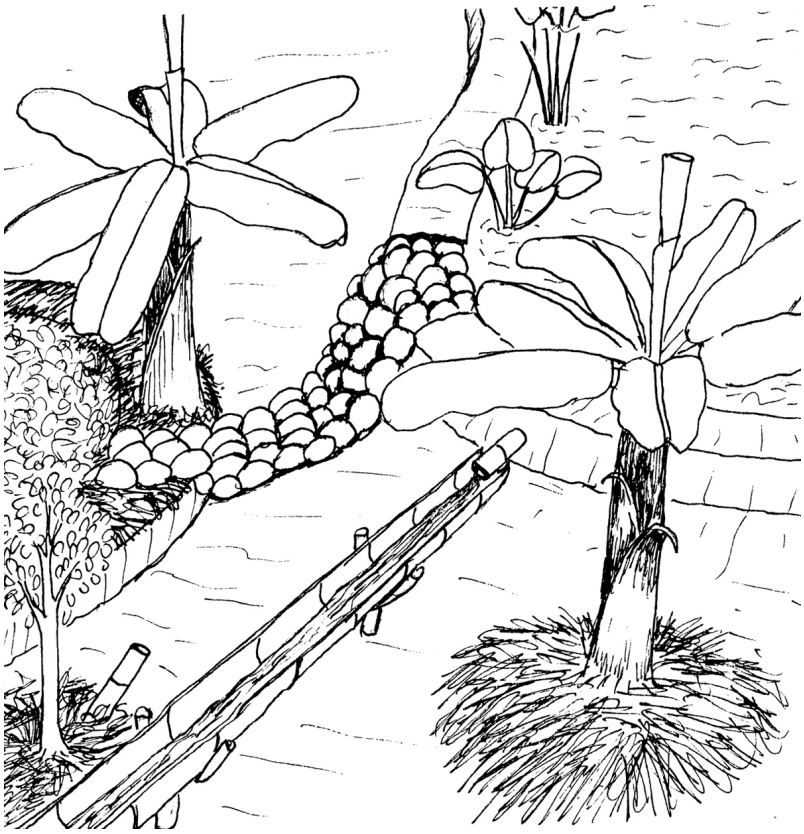
An overflow point is where the water leaves the pond when it is too full.

They prevent pond wall damage and direct the water to where you want it to go. It should be large enough to cope with water from heavy rains. It is the low point in the pond wall, secured with rocks and possibly even cement to stop erosion. Plant a series of small clumping grasses next to the overflow point to secure the soil.

If the pond is in a small gully, it is a good idea to position the overflow to one side, rather than the middle of the pond wall. The middle of the pond wall usually has more pressure and is more likely to leak.

A piece of large bamboo placed in the wall also works well. A piece of wire mesh or shade cloth at the overflow point, or covering the end of the bamboo that is in the water stops fish from escaping. It also helps to keep the overflow clean, which is important if the overflow water runs into another pond. Check and clean the wire mesh or shade cloth regularly.

Try to run the overflow water into rice paddies, swales (read Permaculture Design (**Ch 3**) about swales), banana pits or other water catchments to make use of the nutrient-rich water.



Fish production

Creating an aquaculture ecosystem

When aquaculture systems are functioning and healthy they are an integrated ecosystem. The following steps for fish production create the base for this to happen.

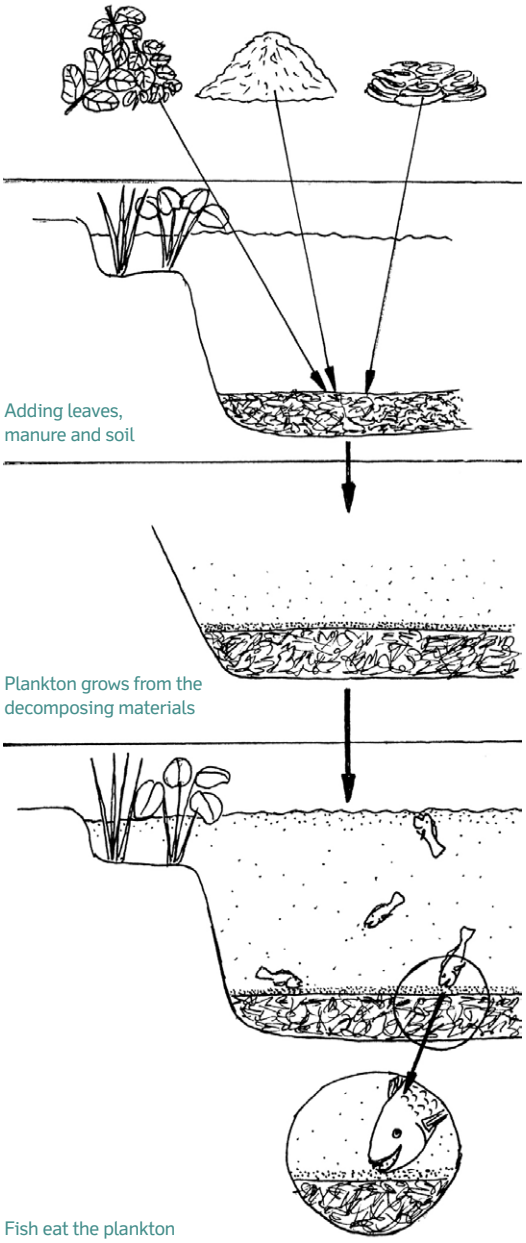
Algae, plankton, plants, fungi, bacteria, insects, frogs, birds, trees, leaves, fruit, manure and other animals and people are all essential elements to create a good environment for raising healthy fish. The fish are also part of the ecosystem as other elements rely on them for food (their manure), balancing oxygen, algae and plankton levels, etc.

Algae are some of the smallest but also some of the most important plants in the fishpond ecosystem. Algae contribute to the light green colour of a healthy pond and, like other water plants, use the nutrients in the water to grow. Algae produce oxygen for fish to breath and are important food for fish health and growth. Algae grow when the fishponds are healthy and when there is food for the algae. Some fish, such as tilapia and silver carp, and many small fishpond animals, eat algae directly for their nutritional needs. Other fish feed on the animals that feed on the algae.

Fish farmers need to know their systems. Careful observation and management are the keys:

- As all elements of the fish pond are connected, the sudden removal of one element has a direct impact on all the other elements: e.g. the removal of too many water plants at once causes oxygen to decrease and nutrient levels to increase, both of which have a negative impact on fish.
- Temperatures, plant-growth rates, types of insects and the variety of food available change with the seasons during the year; each one has an impact on fishpond ecosystems. Types of food, feeding rates and fish-stocking rates – the relationship between the number of fish in a pond and the amount of food available – should be adjusted accordingly.

As with any permaculture system, the goal is to create a resilient, self-maintaining, integrated and productive aquaculture system that uses local resources and is appropriate for the people and place. Experience, observation, sharing knowledge and learning from mistakes are vital parts of the process.



Step 1: Prepare the fishponds

LIME

For new clay ponds, apply lime on the sides and bottom of the pond before adding water. For acidic soil and water the lime balances any pH problems and helps the water to become clear. It also helps to control initial pest and disease problems, and settles the soil and manure on the pond bottom.

The use of lime stimulates bacteria and other microbes on the pond bottom, which increases nutrient availability to other plants and algae in the pond water. Where the pH ranges from neutral to alkaline and the water is reasonably clear, only small amounts of lime are needed.

Apply about 2 – 3 kg per 100 m^2 (10 m x 10 m or 11 m in diameter). It is not essential but it helps a lot for new ponds. Fill the ponds with water and leave them to settle for three days. Then add other materials. Cement ponds do not need lime.

MANURE

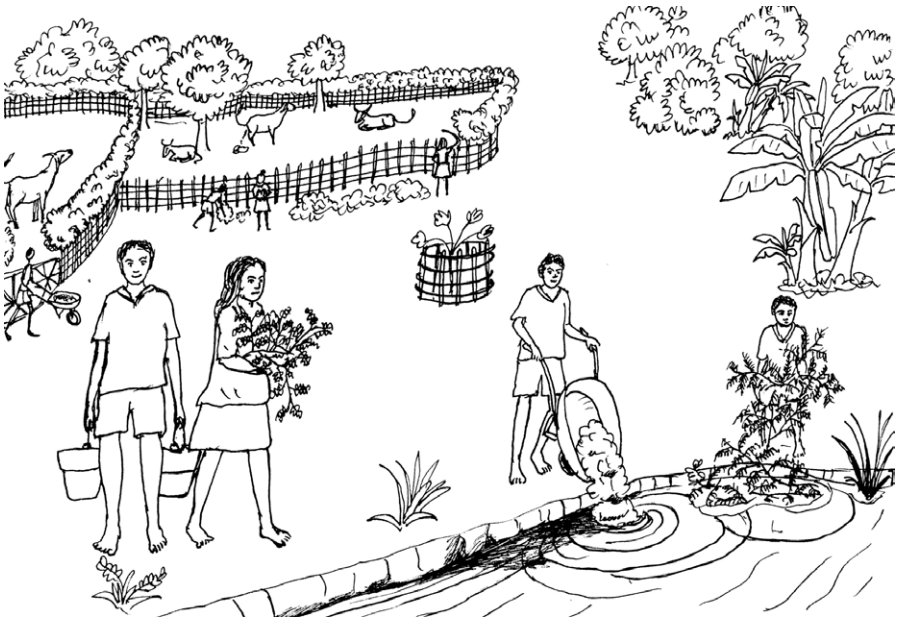
A healthy fishpond starts with a layer of manure and soil on the bottom of the pond. Cow, buffalo, horse, pig, chicken and duck manure are all suitable. Fresh manure is better than dry manure because it has more bacteria.

Use 30 – 50 kg of cow, horse, buffalo or pig manure per 100 m^2 (10 m x 10 m or 15 m x 7 m or 20 m x 5 m, etc.). For a pond 25 m^2 in size (5 m x 5 m or 8 m x 3 m or 10 m x 2.5 m, etc.), use 8 – 12 kg of manure.

Chicken and duck manure are a lot stronger (with more nitrogen and phosphorus,) so apply at 6 kg per 100 m^2 or 1.5 kg per 25 m^2. If you mix chicken and duck manure with other manures, only use half the amount: e.g. for a 100 m^2 pond use 3 kg of chicken or duck manure and 15 – 25 kg of other manures. 1 kg of fresh manure is approximately one large shovel full. 1 kg of dry manure is approximately three large shovels full.

Spread the manure over the whole pond bottom and sides. The manure promotes the growth of plankton, an important natural food source for fish. Using water and soil from an established pond is an excellent starter for a new pond because it adds lots of nutrients, plankton and good bacteria. Add some of this pond soil as well as the manure.

Careful: Make sure you do not to add soil and water from ponds where sick or dead fish have been; you might add a disease to the pond.



Adding manure and leaves to a fishpond

PLANT MATERIAL

Leaves and fruit are also important in a fishpond. Before adding fish, add a large amount of leaves and plant material. This promotes bacteria and plankton growth which provides fish with food. Sesbania, sweet leaf, leucaena or moringa are the best trees to use.

Apply 40 – 50 kg of leaves and branches, tied in bundles, per 100 m^2 (10 – 12 kg per 25 m^2). Place them around the edges of the pond. Remove the branches after a week and replace them with new branches if the water has not turned green. The manure, soil, leaves and other organic matter provide food for plankton, bacteria, algae, insects and plants that all become fish food. This is especially important for cement ponds.

BACTERIAL ACTIVATOR

Add bacterial activator to help speed up the process of preparing the fishponds. 1 litre per 5 m^2 is great but even a small amount helps. The bacteria enable the manure and plant material to decompose faster and help to increase water oxygen over time. Read Soils (**Ch 9**) for how to make it.

Do not add the fish until the fishponds are ready: it usually takes one to two weeks for these materials to settle.

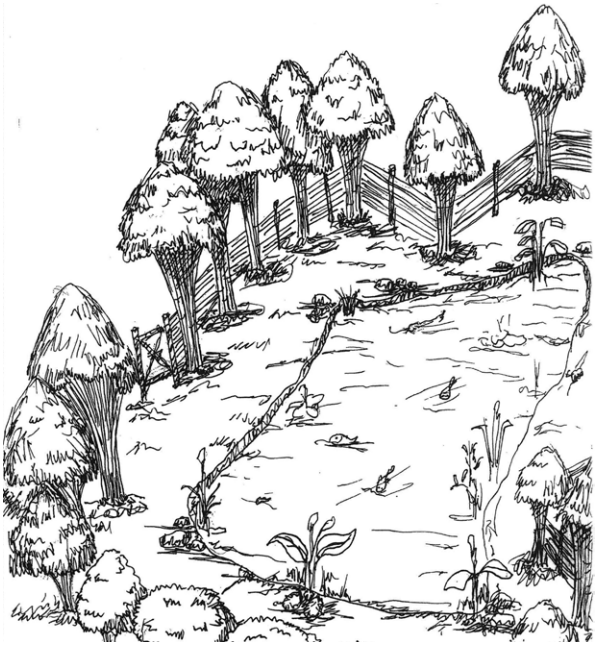
Step 2: Provide shade and fences if needed

The right amount of sunlight and shade is important, as previously mentioned, including the best trees to use. Some shade keeps the fishponds cooler and improves production. At least half a day of sunlight is recommended, and morning sun is best.

Planting trees and bamboo around the pond to provide some shade

Trees and water plants give shade in the long term. If there are no trees, you can provide some shade straight away by making a simple structure from bamboo or wooden poles and palm leaves, or make a structure for growing vines such as luffas, gourds and beans. Structures for shade also protect the fish and other water animals from birds which may eat them.

You might need to build fences to protect the ponds from animals. Living fences grown from plants that you can use to feed the fish is the best long-term solution.

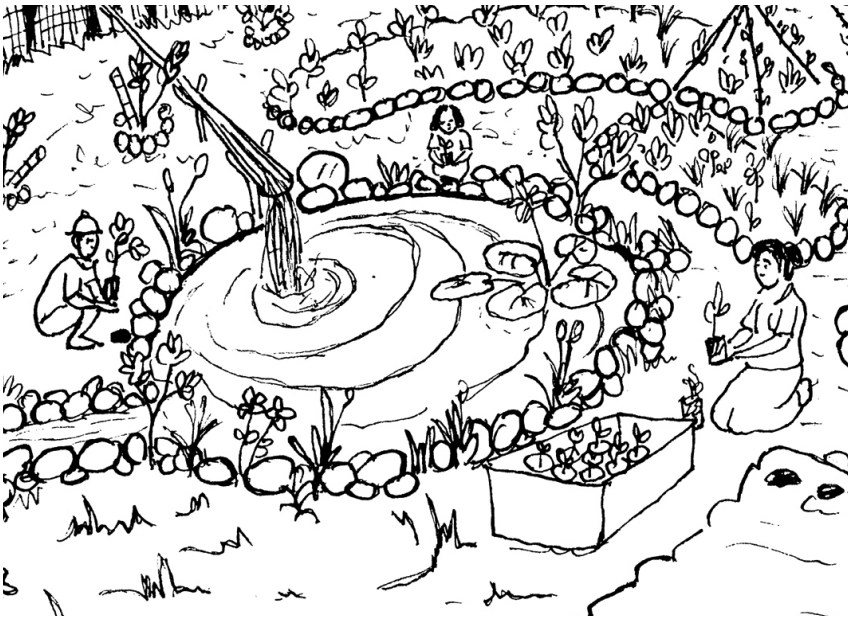


Step 3: Add water plants and animals

It is important to grow many different types of water plants. Each type of plant has a different basic function to keep the pond healthy. Water plants provide a habitat for small fish, food for the fish, a place for plankton to grow, and the rotting leaves feed the plankton and bacteria (also fish food). They are also food for people.

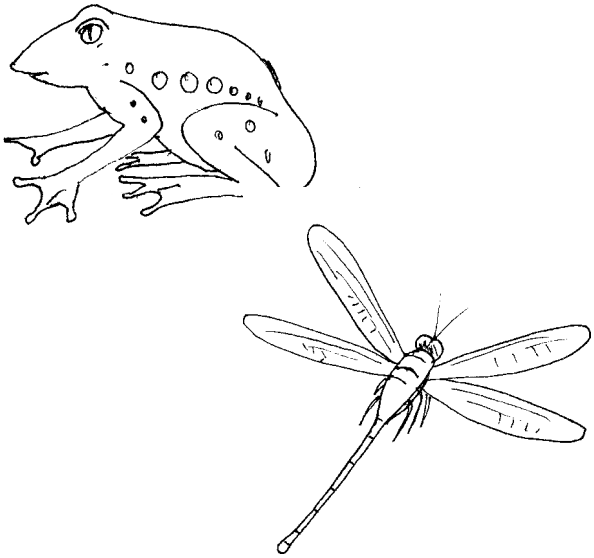
There are:

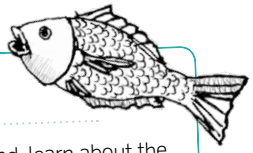
- Plants that grow from the soil: taro, arrowroot, bulrushes, reeds, lotus, water chestnuts, etc.
- Plants that grow from the soil and on top of the water: water spinach, watercress, etc.
- Plants that live on top of the water: water lilies, water hyacinth (*Eichhornia crasippes*), duckweed (Lemnoideae), water fern (*Azzola*), water cabbage (*Pistia stratiotes*), etc.



Many of these plants also act as water cleaners. They absorb excess nutrients such as from fish waste. Plants help to remove many toxins from the water and maintain a healthy pond environment. They also provide fish and other water organisms with somewhere to hide from predators.

Small aquatic animals are useful for fishponds as well. Water snails, small prawns, frogs and other small animals help to keep an aquaculture system healthy and provide food for some larger animals such as catfish.





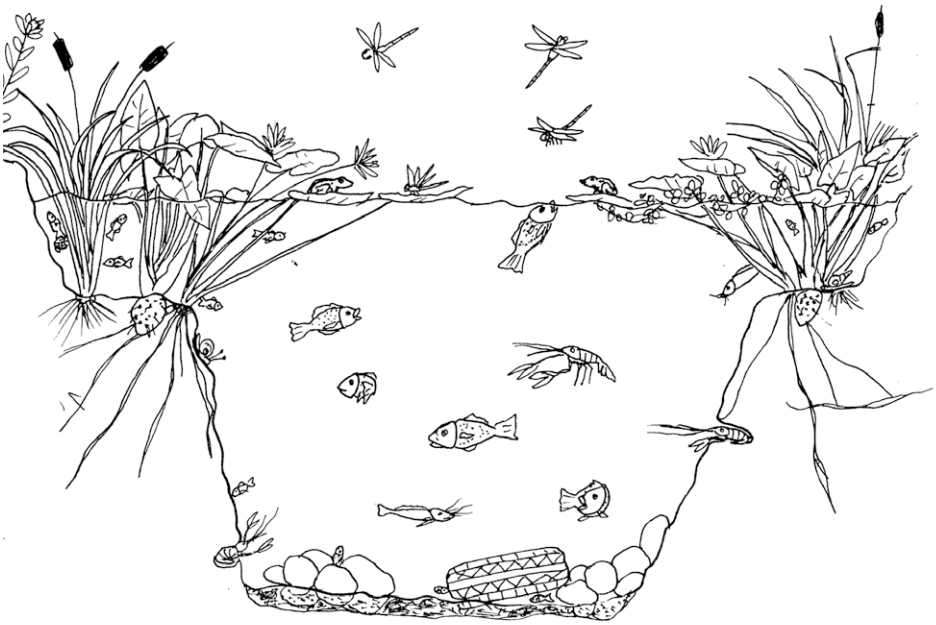
SMART IDEA:

When starting a new pond, learn about the aquatic plants and animals in your area, and which ones other farmers have in their ponds. Add some small animals from your area, such as shrimps, mussels or tadpoles (small frogs), because they will quickly adapt to your environment.

Step 4: Provide homes for the fish

Small fish sometimes need protection from bigger fish, especially if they eat other fish. It is necessary to supply a place for fish to make their nests. All water animals are healthier if they have a good habitat. Piles of rocks, water plants or old drink cans tied together all help to provide shelter, homes and habitat.

Tilapia need shallow water to make their nests. A shelf – described in pond construction for growing water plants – also provides a nesting area for these fish.



Step 5: Plant around the pond edge

For clay ponds, plant vegetation around the edges of the pond immediately to hold the soil together and protect the sides from erosion. These edges make excellent production areas because the plants receive lots of water and nutrients.

Plants to grow:

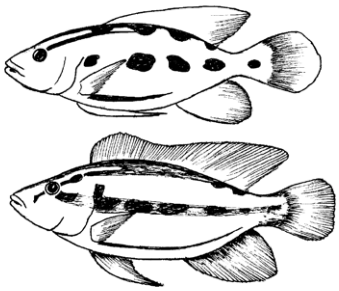
- Water plants: taro, arrowroot, water spinach, watercress, reeds, bulrushes – to provide food and habitat for pond animals
- Grasses – to stabilise the edges
- Vegetables – create small vegetable plots around the edge of the pond.
- Small fruit trees: bananas, citrus, papaya – plant them one to two metres from the pond edge. They love lots of nutrients and will not give too much shade.
- Larger fruit trees: mulberry, panama berry, wax jambu are examples – pick trees you can prune and that do not give too much shade. Plant two to three metres from the pond edge, but don't plant too many or they will create too much shade.
- Legumes and green leaf plants: Moringa, Sesbania, Leucaena, Acacia, pigeon pea, sweet leaf provide many functions including food for the fish. Prune them as needed.
- Small bamboo is excellent. It holds the soil together, and provides shade and good fish food, especially for freshwater prawns and types of algae important for good pond health.

Step 6: Add the fish!

When you add the fish it is very important to add some water from where the fish came from. This adds bacteria they are used to and helps them to settle quicker.

There are many types of fish used in fishponds and these vary from region to region. Common species are:

- Carp
- Tilapia
- Catfish
- Gourami



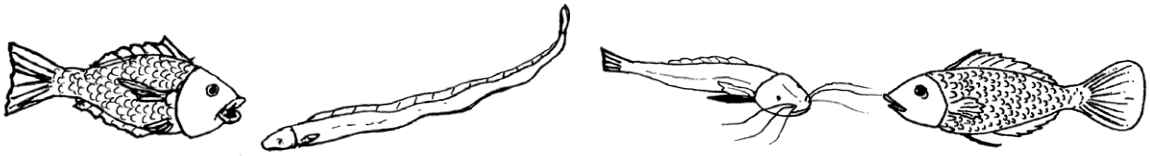
The variety of these species from country to country is huge.

Prawns, crustaceans and eels also grow well in fishponds.

Different combinations of fish types

Fish are divided into three categories:

- **Herbivores** – Fish that mostly eat plants, algae, leaves, grains, etc. Example: types of carp
- **Carnivores** – Fish that only eat meat or animals, including insects, small pond animals, such as plankton, and other fish. Example: eels, catfish
- **Omnivores** – Fish that are herbivores but also eat meat, insects, plankton and other very small pond animals as well. Examples: tilapia, gourami, catfish, types of carp



There are many different types of catfish and carp in the world; some are herbivores and some omnivores. Identify your local species, so you can give them the correct food and get the best results.

A healthy aquaculture system can contain different types of fish. Fish numbers naturally reach a state of balance between the varieties. The different types of fish feed at different levels in the water and maximise the use of food and space in the pond. They also have different roles in keeping the pond healthy.

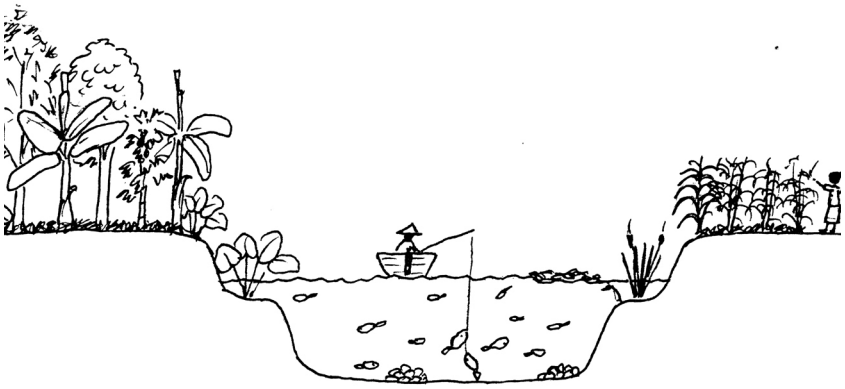
The fish that eat on the top and in middle of the pond eat most of the fish food, including mosquito larvae and other insects: e.g. tilapia. The bottom feeders eat any food and plant material that drops to the pond floor including plankton and other fish food growing on the bottom. They help to keep the pond environment healthy. E.g. carp, catfish.

A larger pond is necessary to have enough room for the different types of fish (5 m x 5 m or bigger is recommended). If you want to have all three categories you must introduce them in the right order.

- First, introduce the herbivorous fish
- Second, add the omnivorous fish when the herbivores are three months or older
- Thirdly, add the carnivores three months after the omnivores.

Most tropical fish are omnivores, but they eat different food. Catfish eat other small fish and therefore you should add them last. The other omnivores usually do not.

Once established, the pond mostly looks after itself, though does require some food and general maintenance. Continuously observe the health of the fish and the numbers of the different fish types. The omnivores and carnivores control the number of baby fish, eating many of them. This helps to prevent the problem of overstocking – too many fish in the pond – which then reduces the amount of food per fish. However, if you introduce them too early, they might eat all the other fish!



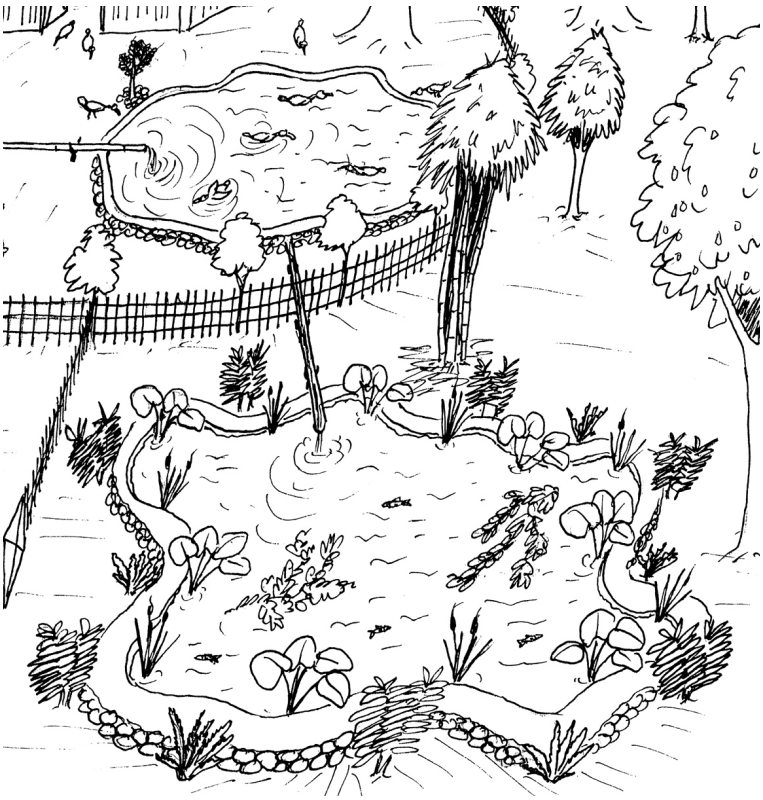
Some protection for baby fish is necessary so that some survive to maturity. Rocks, water plants, old drink cans tied together and plants provide hiding spaces, and a small-netted area or separate small pond for small fish helps too.

Cage for small fish

STOCKING RATES

Having three fish per metre squared is a good number for most fishponds. For a 100 m^2 pond, aim to stock 300 fish. This is for a fishpond that has added manure and leaves as well as some food. The number of fish can increase to five per metre squared with extra food and good management, but the amount of food given must be accurate with the necessary knowledge of good fishpond maintenance.

For the long-term aim of a sustainable and self-maintaining fishpond, raising different types of fish together is the best method.



The following example of stocking rates is a good general guide for a fishpond of 300 fish:

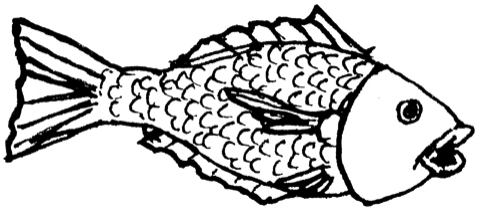
- Approximately 30% (90) – tilapia, gourami
- Approximately 50% (150) – carp, larger tilapia varieties
- Approximately 20% (60) – catfish

Raising eels with other fish can create problems, especially in smaller ponds, as they reduce other fish stocks. Sometimes they naturally enter fishponds from rivers or rice paddies – if so, try to keep their numbers low. Only introduce eels if you are confident of managing them well. It is better to keep them separate and build a wire-mesh fence around the eels' pond as they are very difficult to contain, especially in the wet season.

Types of fish

CAREFUL: Introducing new varieties of fish can create big problems if they enter rivers, lakes and natural water systems. In many areas they compete with local fish and damage ecosystems. It is not recommended to introduce new species; instead use the fish varieties that are already in your area.

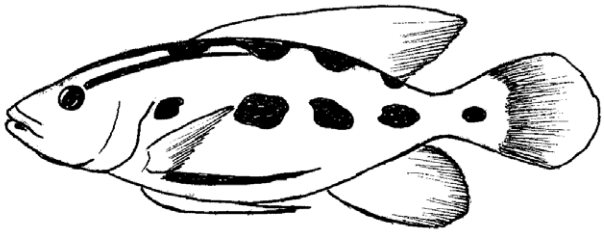
Carp



Carp are common in many tropical countries and are a tough, usually disease-resistant fish.

- **Food** – They mostly eat vegetation and plankton. They feed in the mud at the bottom of the ponds. Add manure, rice husks, leaves, soil, fruit, duckweed, vegetable scraps and other rotten natural materials to feed the carp.
- **Growth** – Carp can grow up to half a kilogram in six months if they have the right conditions and enough food. They can grow to 2 kg or more, but they are tastier when younger.
- **Breeding** – A carp is between eight and twelve months old before it lays eggs. Females lay their eggs all year round on vegetation in the pond. The eggs hatch in two to six days, and the baby fish start eating after two days.
- **Stocking rate** – In a fishpond of 10 metres by 10 metres (100 m^2) you can stock 150 to 300 fish. In a fishpond of 5 metres by 5 metres (25 m^2) you can stock 40 to 75 fish (approximately 2 – 3 per 1 m^2). The levels depend on the amount of food supplied. If there are too many fish in a pond they take a lot longer to grow, they do not grow to full size and are more likely to become sick. In this case, harvest some smaller carp to balance the fish numbers.

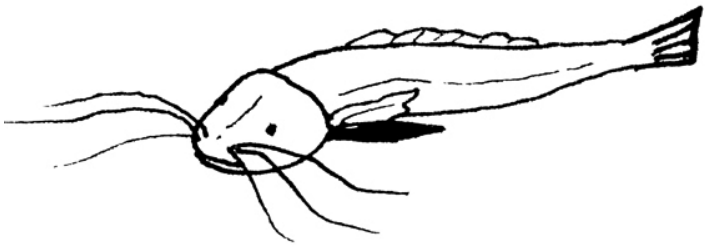
Tilapia



- **Food** – Tilapia eat plankton, water plants and insects. They grow well in healthy ponds which have enough of the food they need. If you supply extra food, such as rice bran, crushed corn, cassava, etc., they grow much faster and the pond stocks can increase.
- **Growth** – Tilapia can grow to 200 grams in six months with a good food supply.
- **Breeding** – They reach sexual maturity after six months and in good conditions they can breed between six and eight times a year. They breed naturally in a healthy pond with shallow shelves or a shallow end. Remove the baby fish as soon as they come to the surface of the pond. Raise the baby fish in separate nets or cages or separate breeding ponds. This makes it much easier to sell the young fish and reduces overstocking problems.

- **Stocking rate** – the ideal rate is three fish per square metre. Tilapias are good fish to stock because they are easy to feed and because they eat mosquito larvae that breed in the fishponds. As they breed so often, problems can occur through overstocking where there is not enough food for the fish. This causes stunting (small fish). You can solve this by :
  - Removing the baby fish as soon as they come to the surface of the pond
  - Adding some catfish into the system when the adult Tilapia are already mature; the catfish feed on the young tilapia and keep their numbers in check.

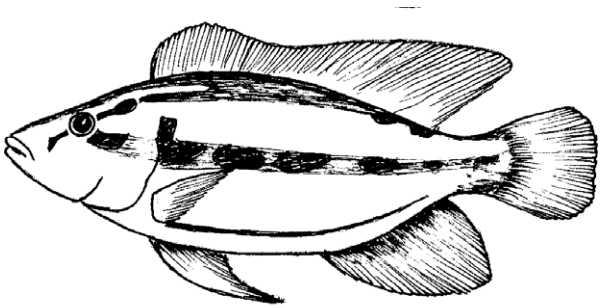
Catfish



Catfish are a very good tasting fish that generally stay healthy.

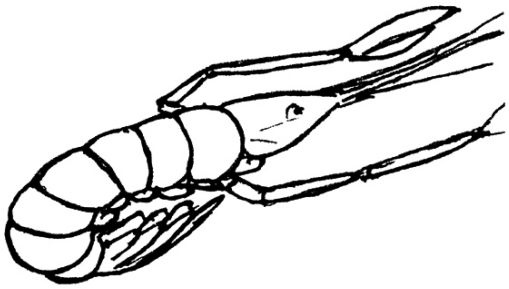
- **Food** – For the omnivorous type: Catfish can find most of their food in a healthy pond system. You can provide extra food, which must include some meat or animal remains. For the carnivorous variety: see the section on carnivorous fish food later in the chapter.
- **Growth** – You can begin eating catfish after six months, but it takes a year to 18 months for them to reach a good size.
- **Breeding** – Catfish carry their eggs in their mouths until they hatch, producing many young. They are hard to breed, so it is easier to collect young fish from rice paddies or rivers.
- **Stocking rate** – Stock catfish at a rate of one to two per square metre. If you want to stock more than a few catfish, you need to provide extra food. This is expensive for a lot of fish farmers. A good idea is to stock a small number (about 1 per 2 m^2), and combine them with other types of fish.

Gourami



- **Food** – Gourami are mostly herbivores but do eat some meat. Their diet consists of water plants, insects, plankton, soft fruit and more. Their growth rates increase if you supply extra food, see the section on herbivorous and omnivorous fish food later in the chapter.
- **Growth** – They can grow to between 80 and 120 grams in six months.
- **Breeding** – Gourami breed naturally but the survival rate of the baby fish is very low.
- **Stocking rate** – It is possible to stock them at high densities of between five to ten fish per square metre, if enough food is available. Gourami prefer ponds with a lot of vegetation in them; therefore they are good to raise with water vegetables or rice production.

Freshwater prawns



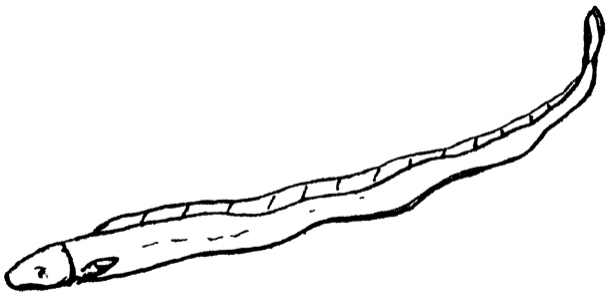
Freshwater prawns grow naturally in rivers and ponds in many tropical regions.

They are very hard to raise from eggs or babies; therefore, a good method is to catch small ones in the river and transfer them to the pond. They readily breed in ponds with established plants. The best time is when the young prawns have shed their last young skin and have just started growing into their adult skin. Before this stage they need special attention, different water temperatures and a variety of food.

The benefit of growing prawns in a pond is that if you increase the amount of food they eat, you can grow more in a small area. They can then grow faster and larger than prawns in the rivers. Grow bamboo next to ponds for prawns and other similar animals. The silica mineral from the bamboo leaves makes their shell stronger; therefore they grow much larger.

Make sure that the prawns get lots of fresh water and have water running into the ponds if possible.

Eels



Eels live normally in many rivers and some rice paddy areas.

They cause problems with stocks of other fish by eating them when they are small. However, experienced fish farmers can introduce the eels in small numbers when the other fish are large, to make a successful pond combination. If it is the first time you are raising eels, it is easier to do so separately; a wire-mesh fence around their pond keeps them in and away from other ponds too.

As they are carnivores, eels can be expensive to grow. The following example is a natural method for raising eels. It works well for a pond size of approximately 3 m x 5 m (15 m^2) or 4 m in diameter.

- First create a layer of mud and manure on the pond bottom.
- On top, put a layer of cut banana stems, then a layer of grass and leaves.
- Repeat this process adding soil and manure, another layer of cut banana stems, then more grass and leaves.
- Keep repeating this process until the pond is full.
- Fill the pond with water and wait until the layers break down, which takes approximately one to two months.
- When the material has all rotted, add between 100 and 150 eels.

The materials provide food and a habitat for insects and small water animals. They are food for the eels.

To increase production, you can supply extra food: e.g. Intestines, blood, bones, ground feathers, animal remains (cooked is best for these foods), or frogs, dead rats and mice, and termites.

Breeding fish

Proper breeding techniques for freshwater fish are often very technical and difficult.

Some fish, such as Tilapia, breed naturally but others need special techniques, conditions and specific equipment. One idea for holding the baby fish is to make containers from bamboo.

The methods are too long to include in this guidebook, so interested people should look for more information. Breeding fish:

- Provides a continuous supply of baby and young fish
- Improves production rates and quality
- Means there are young fish to sell
- The reference section shows you where to find more information.

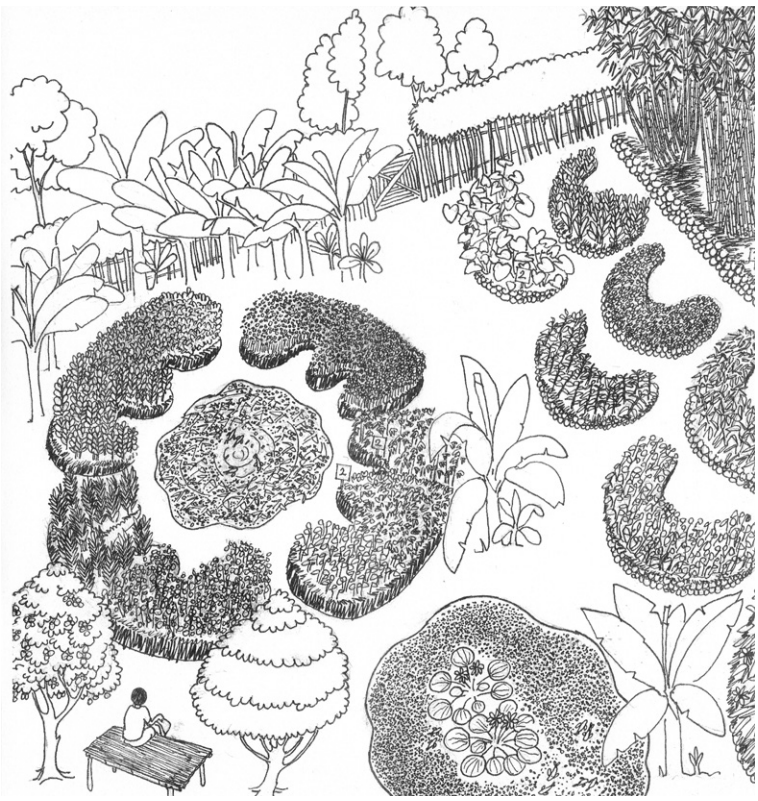
A community aquaculture group is a great way to breed fish, working either as a group or to support one fish farmer to do it. This also helps to share aquaculture knowledge.

Cage for holding baby fish (fingerlings)

Water-plant production

There are many different types of water plants to grow for food, trade and income.

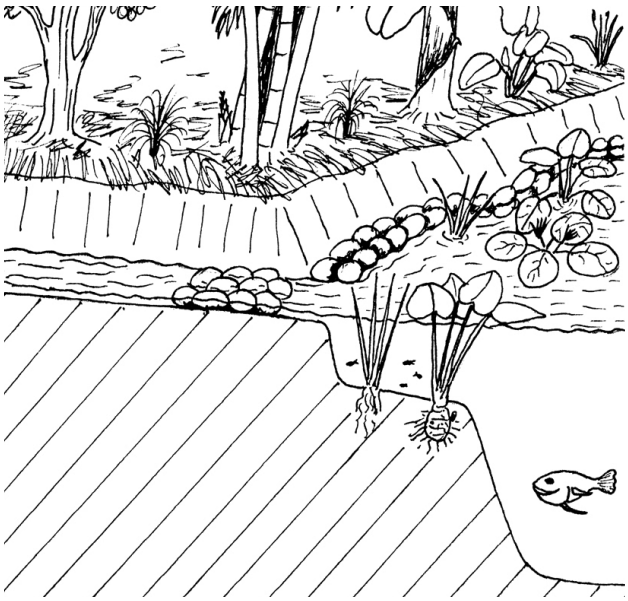
Well-known plants are taro, water spinach, watercress and arrowroot. Lotus and bulrushes are also edible. Cooking lotus leaves, roots and young (unripe) seeds makes tasty food. People also cook the root of bulrushes in the same way as taro.



Ponds used for growing productive water plants

Plant growth is faster if you add a small amount of manure. All water plants need fresh water added from time to time to grow well.

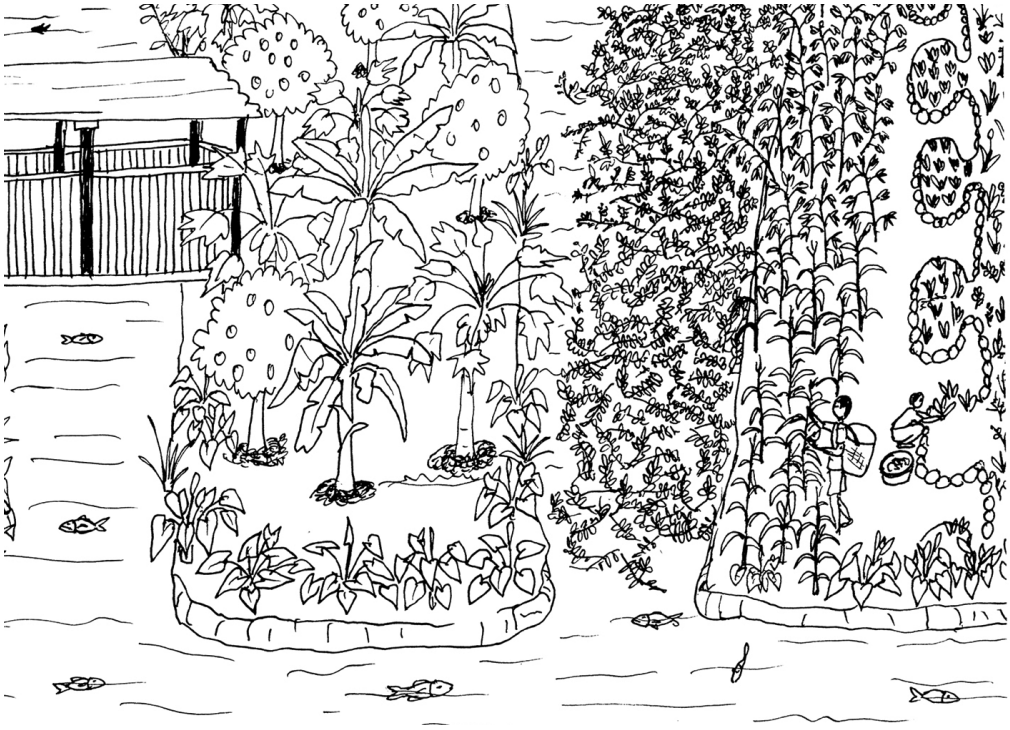
It is easy to grow a combination of fish and food-producing water plants. The plants and fish help each other because the fish manure feeds the plants, and the plants provide rotten leaves and habitat for the fish.



Be careful when combining fish and water plants.

- Control the water plants and harvest them as needed to stop them from growing over the whole pond. Water spinach and watercress grow very fast. This can provide problems for the fish because they take too much light and oxygen. They should cover a quarter of the pond at most. Less area is better.
- Fish have plants they like to eat more than others, the same as people and animals. Observe which plants they like best and find a good balance between fish and plant production.

Plants that you cannot eat, trade or sell you can use as mulch, animal food or in composts and liquid composts.



Collecting water from springs and houses to clean and use for aquaculture

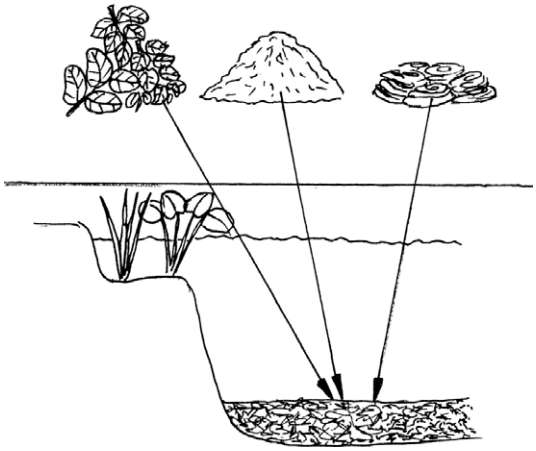
Pond management

Fish food

FOOD FOR HERBIVOROUS AND OMNIVOROUS FISH

Herbivores and omnivores are carp, tilapia, gourami and catfish.

Food for pond maintenance: To provide a continuing supply of food for the fish and to keep the pond environment healthy, keep adding manure and leaves. A week after including the fish in the pond system, start adding more manure, for example, 30 – 40 kg of cow, horse or pig manure per 100 m^2 once a week at 8 – 10 kg per 25 m^2. Or use 5 kg of bird manure per 100 m^2, 1 – 2 kg per 25 m^2.



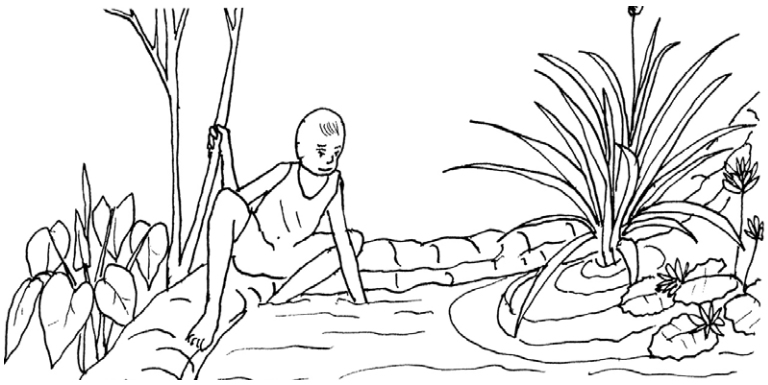
For old fishponds with clean, light green coloured water, reduce the amount to 20 kg per 100 m^2 per week of animal manure, or 3 kg of bird manure.

For fishpond maintenance, animal manure is generally better. The quantity of manure added should be applied according to the colour of the water.

The water colour is very important because it shows how much food is available for the fish.

A good test is to place your hand between 10 and 20 cm underwater. If you can see your hand, the water is too clear.

- If the water colour is clear, increase the amount of manure added until the colour changes to light green.
- If the water colour is light green, the amount added should stay the same.
- If the water colour is dark green, reduce the amount added or stop adding manure until the colour changes to light green.



Checking the water colour

Another sign of too much fertiliser is if the fish are at the surface of the water before dawn, gulping for air. This is because there is too much algae competing with the fish for oxygen (algae produce oxygen during the day through photosynthesis and, without sunlight, they consume it at the night).

Another way to know a pond is over-fertilised is if the fish do not react to normal stimuli – for instance, they do not move when they are scared. This is a dangerous sign as it means the fish are probably dying.

Solutions for too much fertiliser:

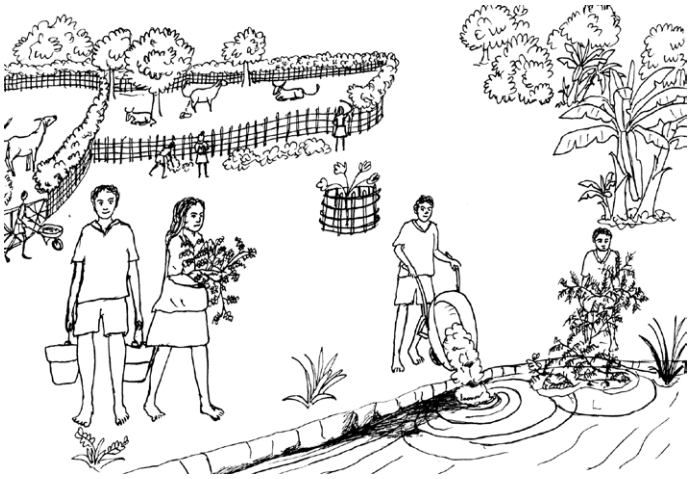
- Stop adding manure immediately.
- Increase the amount of fresh water in the fishpond.
- Add some bacterial activator to help the manure and plant material to decompose faster.

Add small amounts of leaves and rotten fruit occasionally as well; – moringa and sweet leaf are excellent. If there are water plants in the pond, you do not need to add many leaves.

Other factors that can affect water colour include:

- Too much sun – it makes the water colour too dark.
- Too much shade – it makes the water colour too clear.
- Not enough fresh water – it makes the water colour too dark.

The recommended amounts of manure and leaves will keep your ponds healthy. A healthy pond provides enough food for the fish to grow well and be healthy. Once you harvest the pond the manure sediment is excellent as plant fertiliser. Concrete fishpond systems or large-scale fish systems are more likely to need extra fish food.



Extra feeding

Extra food helps the fish to grow faster and allows you to increase the stocking rate – the number of fish in each pond. With good management, the number of fish can double or triple. To give maximum benefit the fish food needs to contain proteins, fats, carbohydrates, energy, minerals and vitamins.

- Feed the fish at the same time twice a day.
- Increase the amount given as the fish get bigger.
- The amount varies from pond to pond. As a general rule, the fish should eat almost all or all of the food in about ten minutes. Observe how much of the food the fish eat each time. If the fish eat all the food quickly then give a little more. If more than approximately 10% remains uneaten then reduce the amount of feed.
- Too much food causes problems by reducing oxygen levels in the pond and large amounts build up on the bottom of the pond.

Types of natural food for herbivorous and omnivorous fish

Grains: These contain proteins, carbohydrates and fats: e.g. broken rice, rice bran, wheat bran, crushed corn, millet and sorghum.

Legumes: Leaves and seeds provide a lot of protein and minerals. Cook the seeds before feeding the fish: e.g. beans, Sesbania, Moringa, Acacia, mung beans, peanuts, soybeans and pigeon pea.

Leaves and fruit: Use them as fish food or to keep the pond healthy. They supply a range of vitamins, mineral, carbohydrates and protein in small amounts: e.g. moringa, sweet leaf, legume trees, panama berries, mulberries, cassava, sweet potato, vegetables and water plants. The fruit trees growing next to the ponds produce fruit that drops into the water, providing more food.

Root vegetables: These provide carbohydrates and energy. It is important to cook them before feeding the fish and only give small amounts: e.g. cassava, taro, sweet potato, yam and potato.

Use a small light or trap above a fishpond to attract insects which then fall into the water and provide extra nutrition for the fish.

Meat or animal remains: These supply the pond animals with proteins, minerals, vitamins and more: e.g. intestines, blood, bones, ground feathers and other animal products that people do not eat. Cook the meat products first to reduce possible disease and worm problems.Termites, frogs, dead rats and mice can also be added.

Oil seeds provide protein and oils, and are low in carbohydrates: e.g. soybean, sunflower, kapok, candlenut, coconut, peanut and mustard.

Kitchen food waste, which mixes a variety of food, is a good source of nutrition for fish.

Carp, tilapia and gourami need very little or no meat in their food. However, catfish grow better if you add some meat when you feed them.

Types of natural food for carnivorous fish

Eels are carnivores and catfish are omnivorous but eat more meat than the other omnivores such as small fish, frogs, worms, insects, prawns, snails and other water animals.

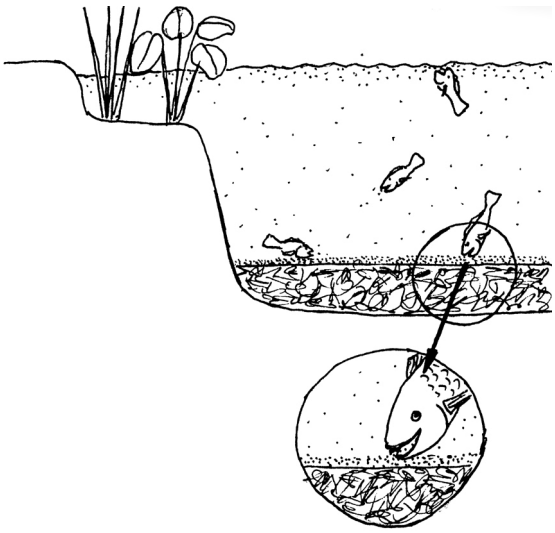
Meat or animal remains can provide the extra food: e.g. intestines, blood, bones, ground feathers, and other animals and fish products that people do not eat. Cook these first to reduce the possibility of disease and worm problems. Termites, frogs, and dead rats and mice are also good forms of protein.

Processed food - for all fish types

Most healthy fishponds supply the fish with all the food they need, perhaps supplemented by naturally available food, so there is no need to give them processed food. However, for some situations making food is a good way to ensure the fish get all the nutrients they need. Processed food is useful for:

- Large-scale fishpond production
- Cooperatives of fish farmers who can make the food as a group and divide it between the farmers
- Small urban ponds where there is a lack of organic manure, plants or other food suitable for fish.

Processing food takes time and money, so it needs large-scale production to make it cheaper. The food also needs proper storage. If you are interested in producing processed fish food look in the reference section for where to find more information.



Fish diseases and pests

DISEASES

The main diseases to watch for are parasites and worms. Some symptoms are:

- Fish trying to scratch themselves on rocks and moving slowly (this might look like flashes in the water as you see the sides of the fish).
- Fish have swollen fat bodies (they are actually very thin but are full of worms).

Use salt solutions to treat parasites and worms. Salt solutions also help to clean fish gills and treat bacterial ulcers. If only a few fish have the disease, treat them separately using salt and water in a bucket. **Always** use water from the fishpond.

Amount of salt to use:

- 25 g/1 litre for 30 seconds
- 10 g/1 litre for 30–60 minutes

When treating the fish:

- Dissolve cooking or sea salt in the water first.
- Stir the water to add oxygen.
- Observe the fish constantly and remove them immediately if they start showing signs of stress.

Placing new fish in a bucket of salt water before adding them to a pond is also a quarantine method to kill diseases.

If many fish are diseased, you can treat the fishpond. Use 1.5 kg/1 m^3 of water (e.g. 10 m x 10 m pond is approximately 100 m^3 if 1 metre deep or 150 m^3 if 2 metres deep in middle). This equals 150 kg of salt for 100 m^3 or 225 kg of salt for 150 m^3.

Always dissolve the salt before adding it to the pond. After one day start adding fresh water as usual. Continuous salt water is not good for water plants, so watch for signs of plant stress. Add more fresh water to dilute the salt if necessary.

Add salt to the water at 2 grams/litre when transporting fish to improve their health as it helps the fish to protect their scales.

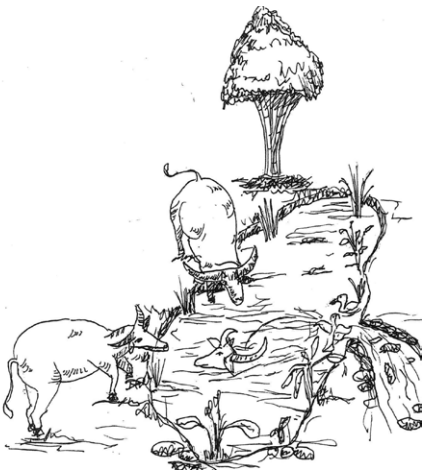
Formalin is another treatment to use if the fish are scratching and moving slowly, but try the salt treatment first. Put 10 litres of water in a bucket and add 2 ml of formalin. Put the diseased fish into the bucket for 15 minutes; then put them back in the pond. Make sure you wear protective clothing and gloves, and wash thoroughly after using formalin as it is very toxic.

By first adding lime to the empty pond after construction you can reduce the chances of worm diseases. Read above at Step 1 – Preparing the Fishponds in the section on fish production.

For any disease, especially after treatment, it is very important to add lots of fresh water to the fishpond and, if possible, to change the pond water completely. This reduces the chances of the disease happening again and it adds oxygen to the fishpond.

Pests

Animals, such as buffalo, ducks, cows, pigs and goats, can cause a great amount of damage to pond edges and eat pond plants. If there are animals close by, grow living fences around the fishponds to keep them away.



Buffaloes and ducks damaging a fish pond

The main pests are birds and humans. Snakes and crabs can sometimes be a small problem, though these pests will always be around. If you attempt to kill the birds, snakes and crabs the problem will only go away temporarily because more will come, especially birds. By killing them you will stop those animals from providing important benefits – birds eat many pest insects as well, snakes eat mice and rats, and they are all part of a healthy ecosystem.

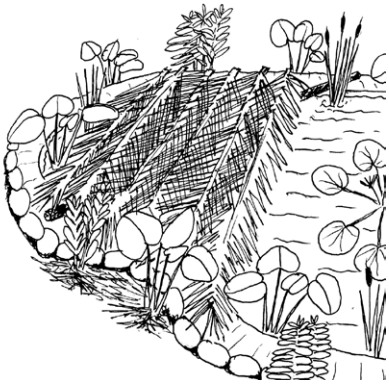
A fence will protect the pond from animals

It is more important to prevent the problems if possible and minimise any potential damage.

BIRDS

To prevent bird attacks:

- Provide fish homes and shelter in the water: e.g. rocks, water plants, tin cans.
- Cover part of the pond with coconut palm leaves to stop the birds from diving in.
- Provide a deep area (2 m deep) in the pond for the fish to escape to.



Coconut leaves provide protection from birds

HUMANS

Communities or individuals living nearby may also create problems for the fishponds:

- If a community decides to construct the fishponds as a group, it greatly reduces any potentially negative actions as there is a common interest to protect them – everyone benefits when the fishponds are productive.
- Make sure the benefits from the fishponds reach others in the community by providing, exchanging or selling knowledge, tools, plants and even baby fish or by helping other communities who want to start fishponds as well. This reduces potential problems of social envy.

Oxygen

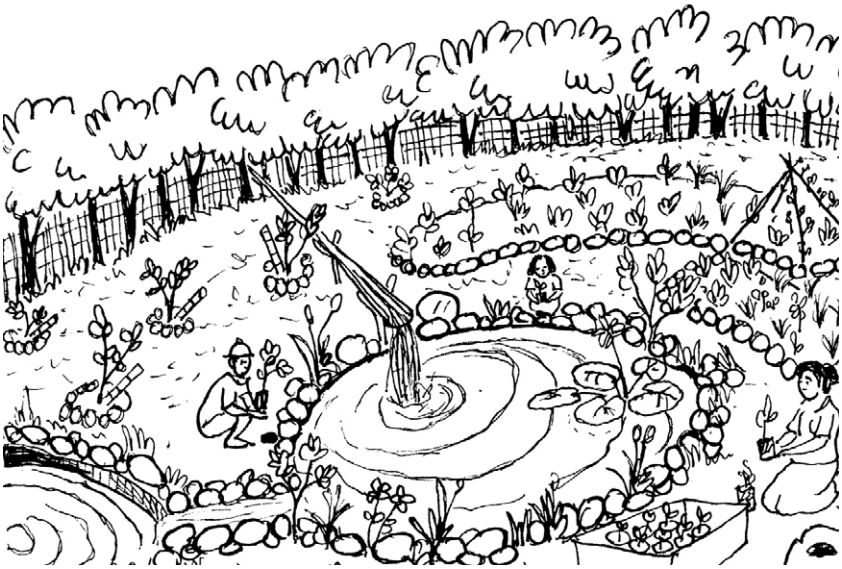
Oxygen – in every drop of water – is essential for a healthy pond. All fish, water animals, water insects, plants, algae and bacteria turning rotting leaves into nutrients need oxygen to live. As there is less oxygen in warm or still water, the fishpond MUST have regular inputs of oxygen. A lack of oxygen can cause serious problems for aquatic animals and plants. Low oxygen levels can be the result of:

- Stocking too many fish
- Not having the right amount of algae or water plants
- Not providing enough fresh water
- Giving too much food
- Adding too much fertiliser
- Not enough sunlight – caused by too many trees or water plants

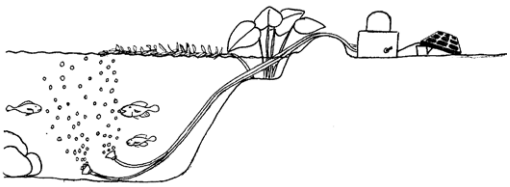
If the fish are at the water surface in the early morning, are opening and closing their mouths, and do not respond to surprise stimuli, there is probably a lack of oxygen in the water. Fertiliser application and extra feeding must stop immediately.

Replace or increase oxygen by:

- Cutting back or reducing the number of water plants and/ or shade-giving trees to appropriate, manageable levels
- Running water into the fishponds – it is the best way to add oxygen. If there is a continual water supply, only a small flow is needed.
- Adding fresh water regularly every few days, especially for small ponds



Other oxygen-increasing techniques include:



Solar water pump

- **Good pond design:** A deep pond stays cooler than a shallow one and cold water holds more oxygen than warm water.
- **Wind:** wind moves the surface water and helps put oxygen back into the pond.
- **Water pump:** a water pump sits in the pond and creates water movement, adding oxygen to the water. Small solar pumps are becoming cheaper all the time and are an option for small ponds.
- **Water wheel:** A water wheel is a small machine that spins the water around, adding oxygen as it spins. Common in Southeast Asia, it uses electricity, petrol or solar power. You can make a water wheel out of an old bike with paddles on the back wheel to create splashing.

Moving the water around with a stick, creating as much splashing as possible. More splash equals more oxygen!

Cleaning the ponds

It is important to clean the pond to stop it from filling up with soil, rotten materials and fish manure.

The best time to clean the pond is after harvesting the fish. Clean it after each or every second harvest. If a pond has both younger and older fish, so therefore never has a complete harvest, catch the fish in a net and keep them in a separate pond or other water until the pond is clean.

Leave a very thin layer of soil/manure on the bottom so that the good bacteria stay in the pond. The soil/manure that you clean out is an **excellent** fertiliser and very strong. Use it for:

- Fruit trees
- Adding to compost and liquid compost
- Vegetable gardens – do not place the rich soil close to young plants and do not apply too much at once. Add it to the garden beds two weeks before planting. The integrated compost/garden bed systems explained in Family Gardens (**Ch 10**) is also a good way to use the manure

Cleaning a fishpond and using the high quality soil as fertiliser

Potential problems

POLLUTION

Pollution in your fishponds causes big problems and can even kill the fish.

Do not allow any water with chemicals, oil or petrol to enter your fishponds.

Water with washing powder – grey water – also **must not** directly enter fishponds. It can ONLY enter fishponds if it first goes through a separate cleaning pond.

Chemicals such as pesticides and herbicides are very dangerous. To reduce the chances of pollution do not use them on land above your fishponds because it may enter the water supply, especially in the wet season.

Pollution carried in water can come from a long way away, especially if you are using river water. Work with the community to reduce the amount of chemicals and rubbish that may enter into the water. This benefits everybody, and the plants, animals and ecosystems of the water catchment.

OVERFEEDING

If you give the fish too much food, it causes problems with the water quality and the amount of oxygen for the fish.

Manure, leaves and rotten fruit need time and oxygen to turn into fish food so carefully and continuously check the water colour.

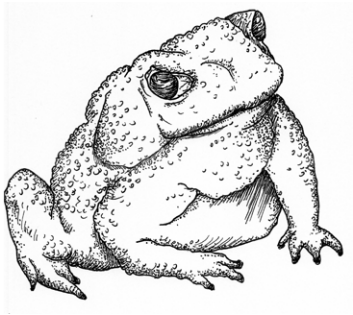
If you are also feeding the fish, do not let uneaten fish food build up on the bottom of the pond. If the problem is bad, an emergency solution is to change the water and clean the bottom of the pond.

MOSQUITOES

Mosquitoes carry malaria, dengue fever and other sicknesses. They lay their eggs in fishponds and the mosquito larvae live in them until they turn into flying adults. Some types of fish eat the eggs and mosquito lavae, therefore stopping the problem. Tilapia are best, but all the other types of fish eat some as well, as do frogs.

Neem leaves added to fishponds can stop mosquito problems. If mosquito larvae are present, place a cup of neem fruit/seeds and four cups of neem leaves in a cloth with a rock, tie it up then sink it to release the neem oil slowly into the water. Replace the neem cloth every three months. The neem stops the mosquitoes from breeding but does not harm the fish. Do not attempt to treat the mosquito problem with other natural pesticides because they might harm the fish.

POISONOUS TOADS



Some tropical countries have the problem of introduced poisonous toads and they cause a great deal of damage to local ecosystems. Sometimes poisonous toads can negatively affect fish populations if the fish try to eat the young toads. If you want to prevent them from breeding, grow thick grasses, sedges or reeds around the ponds or build a low wire fence (30 cm high) because they cannot jump very high.

Other fishpond benefits

They provide vegetables for home use and for sale at markets.

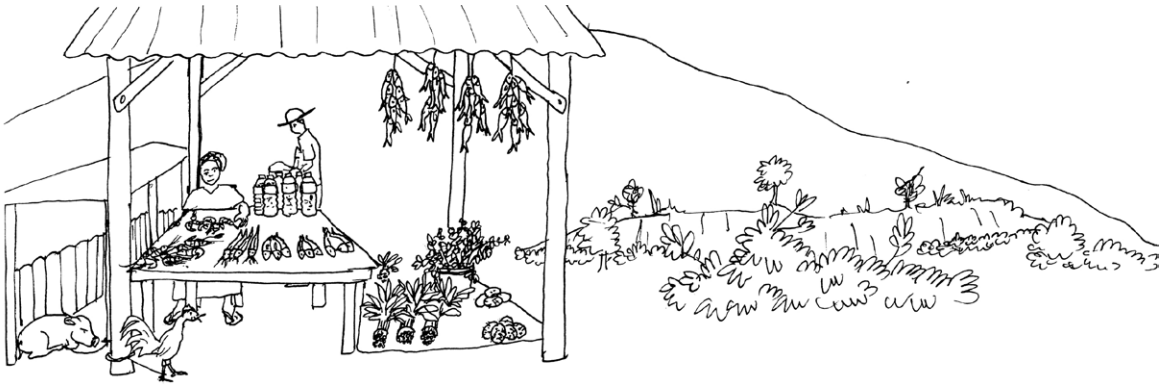
A healthy aquaculture system is home to many frogs, lizards, pest predators and helpful insects. These animals naturally reduce the number of pests in your garden.

The water attracts birds, bees and other small animals that improve the pollination of your fruits and vegetables.

The water makes the temperature around it cooler and more comfortable. This benefits people, plants and animals.

Fishponds are great for water storage and, if they are big enough, you can also use them for watering family gardens and animals, especially at the end of a dry season.

Fishponds are also a great way to educate the community, especially children, about the environment. Water is the most important part of all ecosystems, communities, cities and economies; without it all the plants and animals would disappear.



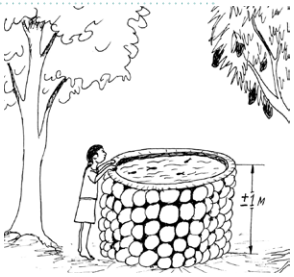
Wet-season fishponds

A wet-season pond is beneficial where there is no or only a minimal water supply in the dry season. Wet-season water must be regular; rains are usually not enough, especially to keep the water fresh. Trenches, swales and irrigation pipes can increase the water inflow. By digging them above the fishponds with the overflow points running into the fishpond, every heavy rain will supply extra water for the ponds. Read Permaculture Design (**Ch 3**) for how to make and use swales.

Soil traps to keep the water clean are necessary if you use swales or soil-lined trenches, or if the water comes from a river. The amount of oxygen in the pond water reduces if the water supply is not regular. You are likely to need extra methods to keep oxygen levels in the water at a suitable level.

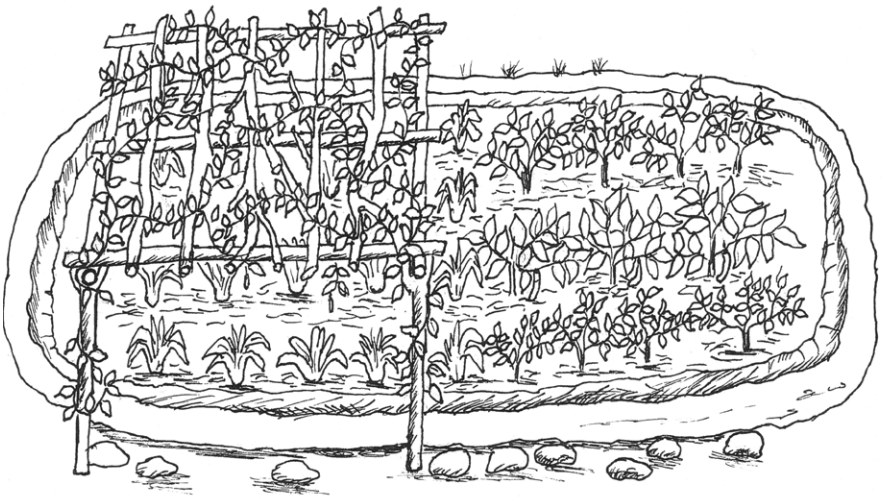
SMART IDEAS:

- You grow bigger size fish if you first raise them for a month or two in a separate water tank and move them into the pond at the beginning of the wet season.
- If in the dry season you do not use the pond or if there is only a small water supply, the bottom of the pond can grow vegetables.
- Wet-season ponds that stay moist and muddy all year are excellent for growing mussels and similar animals that live in the mud.
- A wet-season pond can also grow water vegetables.
- A trellis over the water can grow luffas, gourds, cucumbers and other vines. It reduces evaporation rates, but be careful that it does not create too much shade.

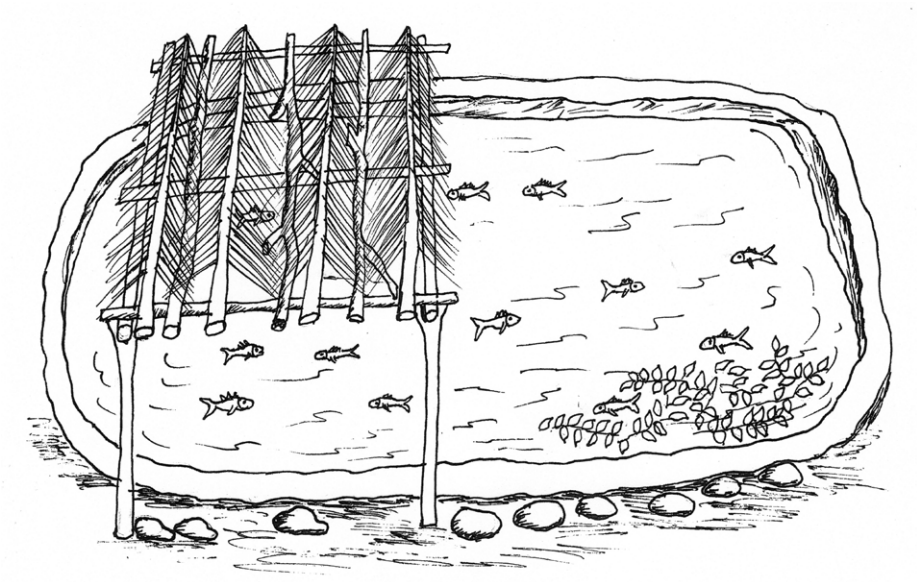


Fish breeding tank

- Cement ponds are easier to maintain but more expensive and cannot grow vegetables in the dry season.
- Clay ponds will probably crack in the dry season. Fill in the cracks with more clay once the first rains come. Add some fresh cow or buffalo manure to aid this process.
- Both types of ponds last much longer if you cover them with palm leaves during the dry season.
- Make long, narrow, shallow ponds specifically for growing wet-season water vegetables. These ponds can also be for vegetable growing in the dry season.



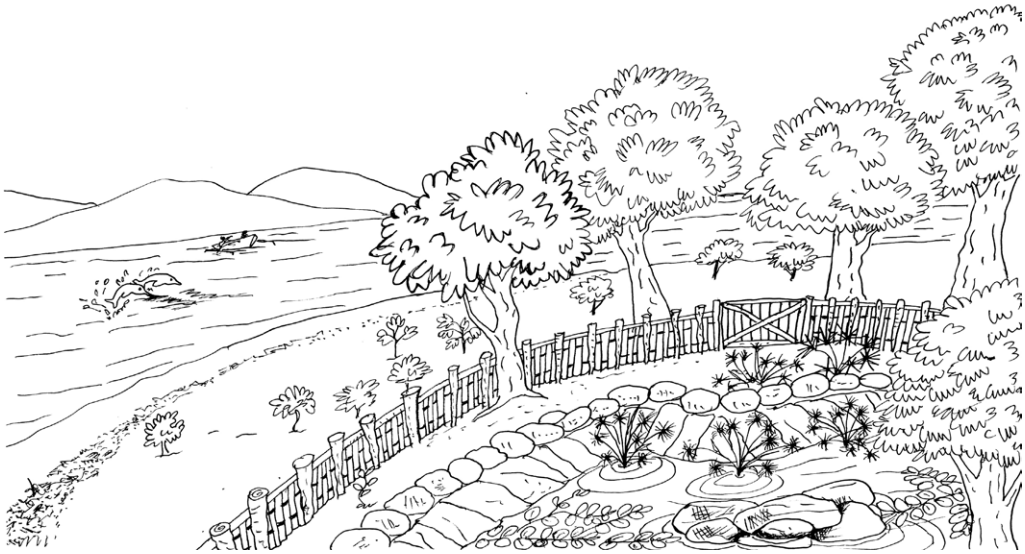
Dry season vegetable growing



Wet season fish pond

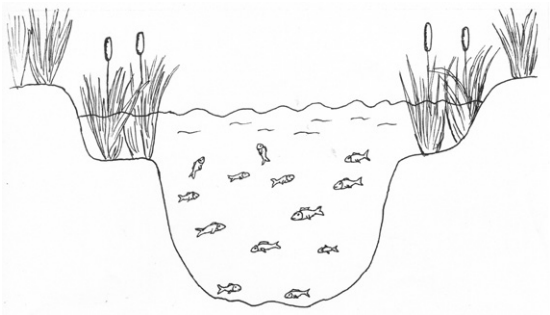
Salt-water fishponds

Fishponds can use salt water as well. A hole dug close to the sea naturally fills with salt water. The fishpond land must not be much higher than sea level or it will take a long time to dig down to the water! The best areas to make them are where the land already has salt water and water plants growing (swampy areas).

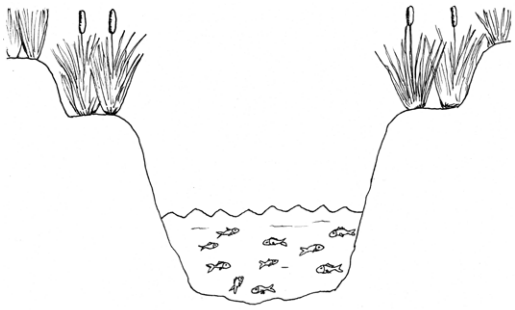


By making a fishpond you create a productive area on land of low fertility. However, be careful not to change the natural environment too much or damage the surrounding land because these areas are very important for keeping the coast and sea healthy. Work with the ecosystem to create an area that is as natural as possible, using local plants that enjoy the salty conditions. This is also important for providing fish food. Stock the pond with fish that like salty water; use local varieties if possible. Choose fish and plants that are easy to manage.

Salt-water pond design and positioning **must** consider the rise and fall of the sea level with the tides. Make sure the ponds are deep enough in the middle so that even with the lowest tide each year there is enough water in the ponds for the fish to be healthy.



Highest tide



Lowest tide

Construction and maintenance

- Use the same ideas for pond size and shape as for normal fishponds.
- Rocks and plants are important to protect the edges and stop erosion especially if the soil is mostly sand.
- Rocks and other forms of fish shelter in the ponds give protection from birds.
- Some shade is essential to help to keep the water cool, especially during the middle of the day.
- A fence may be necessary to protect the pond and plants from animals.
- A healthy fishpond with water plants provides all the food that herbivorous fish need; omnivorous and carnivorous fish will need extra food.
- Once it is established the salt-water pond does not need much maintenance.
- Special consideration is essential in areas where crocodiles may come. Strong fences are necessary around the fishponds to protect the fish (and people) from the crocodiles!

Fish integration with other systems

There are many other food production systems that can integrate with fish:

- Pigs, chickens and ducks
- Vegetables, grains, rice, bamboo and fruit trees

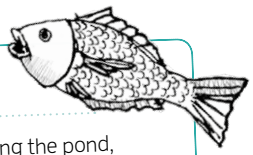
The following examples show strategies and techniques for integration. You can use these and build on them to try your own strategies and techniques.

Chickens and fish system

Common in many tropical countries is building a chicken house over a fishpond. A slatted floor allows the chicken poo to fall through into the pond. The number of chickens varies according to the size of the fishpond, the amount of fresh water and the number of fish:

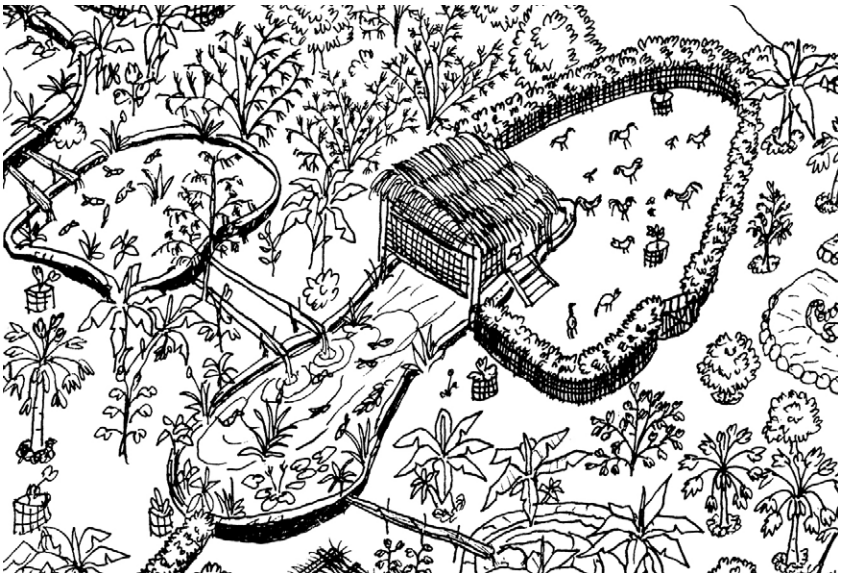
- 25 m^2 pond (e.g. 5 m x 5 m or 6 m in diameter) – five chickens
- 100 m^2 pond (e.g. 10 m x 10 m or 11 m in diameter) – 5 to 10 chickens
- 1,000 m^2 pond (e.g. 20 m x 50 m or 35 m in diameter) – 0 to 50 chickens

The chicken house needs to provide protection from rain and strong winds and allow good ventilation.



SMART IDEAS:

- Plan where the chicken house will go before building the pond, especially if the pond is cement.
- Make sure that the chicken house is easy to access and strong enough to hold a person for cleaning.
- Make sure that predators cannot enter the chicken house.
- Use metal poles if building the house in the water to prevent rotting.
- For small or narrow ponds, place the supporting poles across the pond rather than in the water.



The chickens can spend most of the day out looking for food and go back into the chicken house at sunset. Keep them in the house until mid-morning so that they lay their eggs in the chicken house. Feed the chickens late each afternoon in the chicken house. Use ground corn, rice and beans, and some fresh leaves and weeds. This brings the chickens back to the house each night and also feeds the fish. Provide them with drinking water too. Do not keep the chickens in the house all the time – they need to scratch the ground and eat insects.

The chicken/fish system is great for raising young chickens. The house above the pond protects them from predators and the extra food improves their growth.

The extra nutrients from the chicken manure means you must add fresh water to the pond once a week so that the water overflows. This keeps the pond water fresh. Use the nutrient-rich water as fertiliser. Clean the pond every one to two years. Watch for signs of too much manure.

Benefits:

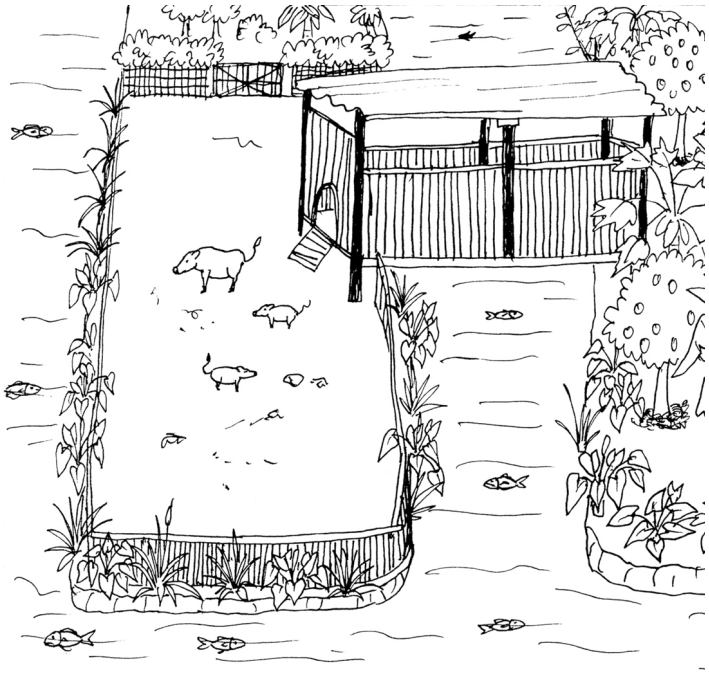
- The chicken manure and excess food drops through the floor or you can sweep it out to provide fish food and nutrients for plants and algae.
- The fish and plants grow faster.
- The chicken house provides some shade for the pond.
- The eggs from the chickens are easy to collect.
- Water plants can provide chicken food (duckweed, watercress, water spinach).
- There is excellent fertiliser every time you clean the pond.

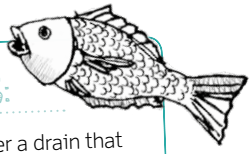
Pigs and fish system

A pigs and fish system is similar to the chickens and fish system.

Use two or three pigs at a time for ponds of ten metres by ten metres or larger. The house construction changes to suit the pigs. Make sure that the pond water overflows regularly, and make good use of the overflow water. The pig house can raise young pigs from two months old for six months and then change them for new piglets. While the pigs are out each day they need a fence to control them; do not just keep them in their house.

Manage the pig food carefully to prevent too much oil from entering the pond. Excess oil can harm and even kill the fish if too much enters. Also, do not to clean out the pig house using any detergents or bleach. You should not do this anyway, but if you do it with fishponds underneath it will kill the fish.





SMART IDEAS:

- Build the pig house over a drain that runs into the fishpond rather than over the fishpond itself. This way you can regulate the amount of fertiliser and feed that enters the water; if there is too much, divert the water away to other ponds instead or use it for making composts.
- In China, people compost the pig manure and waste food and add it to fishponds.

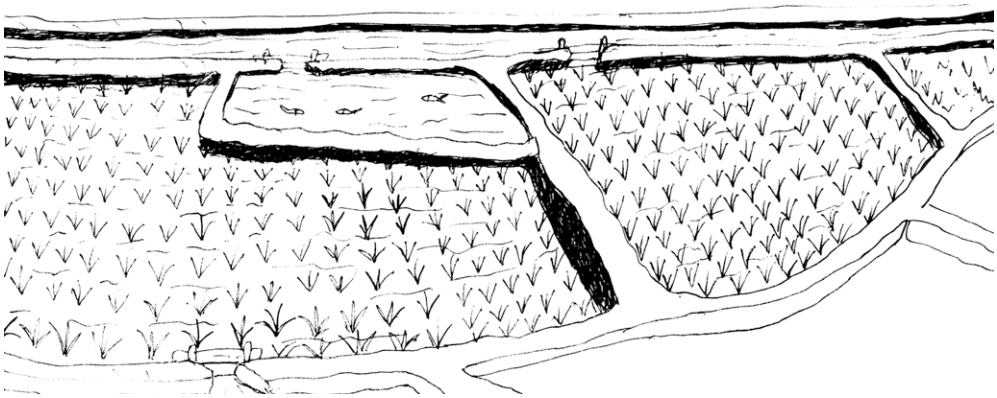
Rice paddy and fish system

Often some fish live naturally in rice paddies such as catfish. You can also raise other types of fish, such as tilapia, gourami and carp, in the rice paddies.

The paddies need to be able to hold water for three to four months, and herbicides you will be free from pesticides and fungicides.

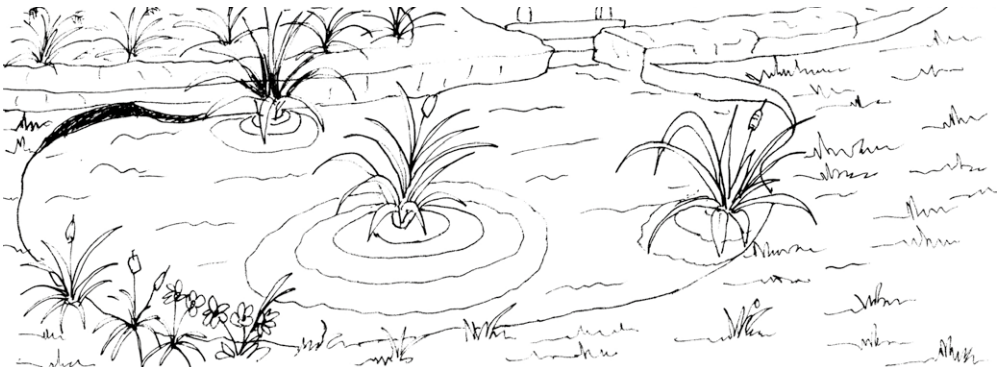
It is best to use paddies close to the house so that management is easier. It is also much easier to combine fish and rice if the paddies are close to a river or constant fresh-water source.

Raise small fish in a separate fishpond and add them to the rice paddies after the rice begins growing. This greatly improves the survival rate of the small fish and prevents fish eating the young rice plants.



Rice paddy and fish system with a separate breeding pond for fish

A separate, deeper pond connected to the paddies is also very important at harvest time. The fish escape to it when the paddy water gets too hot and when the paddies dry up before harvest. Put it at the low end of the paddies. Manage this pond in the same way as a normal fishpond.

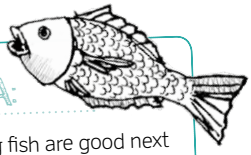


Separate deep pond for mature fish at harvest time

Control water flow and fish movement between the pond and the paddies by using a trench and a removable door.

Benefits:

- There are two different types of production from the rice paddies – rice and fish.
- Some of the fish – e.g. tilapia and gourami – eat the mosquito larvae and reduce mosquito problems.
- The rice plants benefit from the fish manure.
- The fish may feed on the pest insects that damage the rice.
- The rotten vegetation from the rice plants creates fish food.



SMART IDEA:

Small ponds for young fish are good next to irrigation trenches that flow into the rice paddies. It is then easy to use the irrigation water to supply the ponds.

DANGER - If you use pesticides and herbicides you will kill the fish.

Even some natural pesticides, such as derris and tobacco, are too strong. (Derris has roots containing the insecticide rotenone and is commonly used in many places as a fish poison!) Use IPM techniques to manage the rice crop and be very careful with natural pesticides.

Ducks and fish system

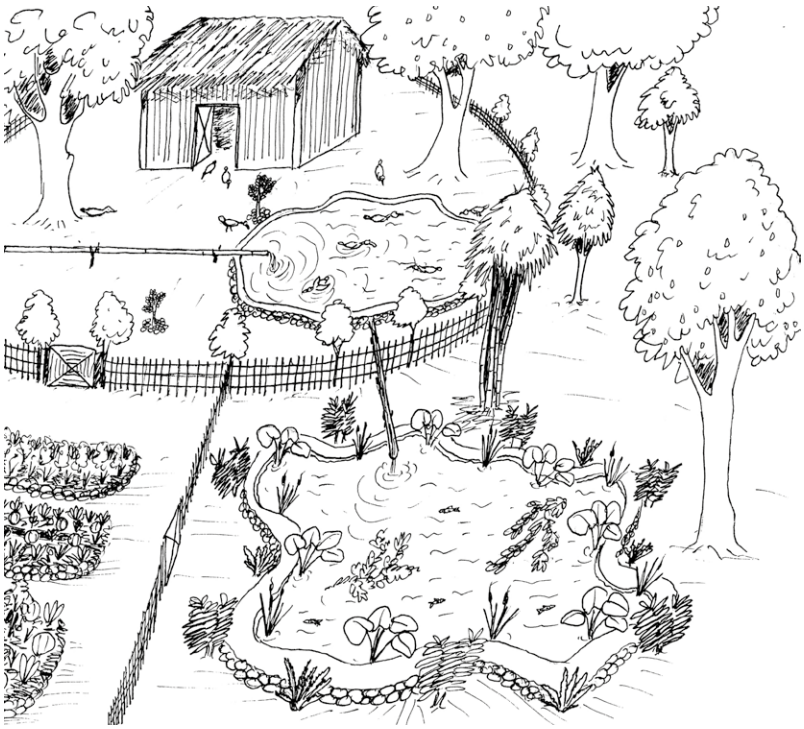
Ducks are a useful and highly productive animal. Raising ducks with fish requires large ponds, a lot of infrastructure and careful management. However, there are methods for simple integration that still provide many benefits.

Make a small separate pond above the fishponds for the ducks to swim in. The water overflowing from the duck pond into the fishpond contains a lot of duck manure and therefore many nutrients. Keep the ducks away from the fishponds because they damage the pond edges, and eat fish and water plants.

Manage duck movement by:

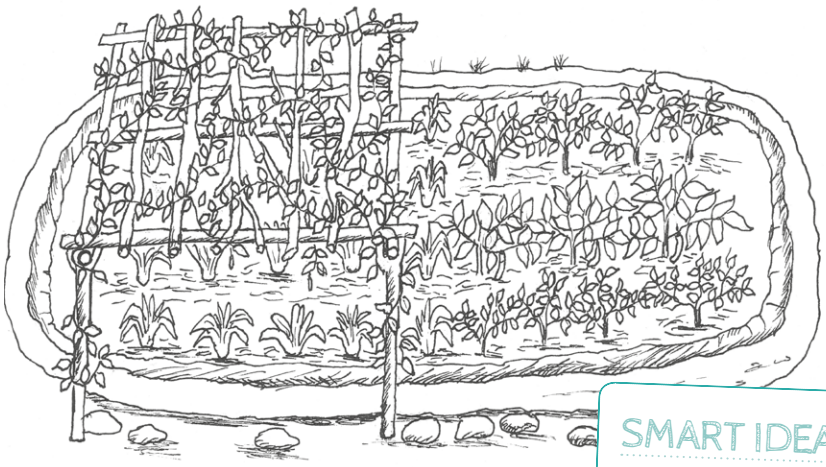
- Building a low fence around the duck area and pond, OR
- Building a low fence around the fishponds
- For small fishponds you can make a lattice cover out of bamboo. Make sure some light still gets through.This cover also protects the fish from other birds

Ducks need a house and food, the same as chickens. They can go out during the day to look for food and return to the house at sunset for feeding and sleeping. The ducks need fresh water to drink each night as well.



Growing dry-season vegetables

Clay fishponds can grow vegetables as well. The soil in the bottom of the fishponds is very high in nutrients from the manure and leaves added to the pond during fish production. It builds up to create pond "mud".



SMART IDEAS:

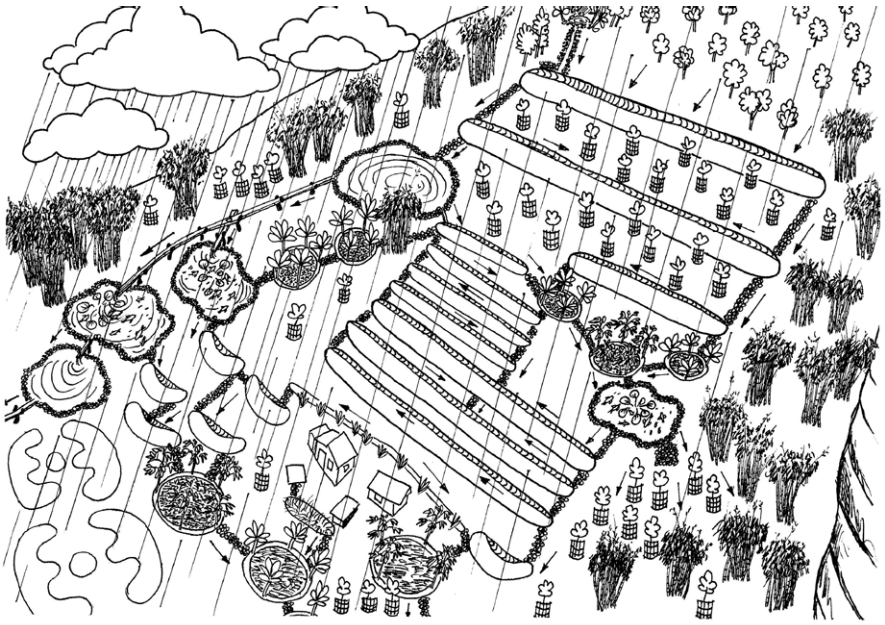
- Do not dig through the clay layer beneath the pond mud
- Plant vegetables that grow for one season only and leave the roots in the ground after harvest
- Grow vegetables organically because chemicals will damage future fish health and the pond ecosystem
- At the very end of the dry season or at the beginning of the wet season, sowing a fodder crop in the pond bottom is a valuable food source for fish when the pond fills with water

Integration with water catchments

SWALES

Swales, described in Permaculture Design (**Ch 3**), catch and store rainfall. With heavy rains, water can flow from one swale to another and then into fishponds. Swales can also collect the water that flows out of the fishponds. Use other types of water catchments as well, such as small dams, banana pits, boomerang swales and terraces.

If swales are at the same height as the pond, fish can swim into the trenches between the swales when they have water in them. This means there is more food available for fish during the times when the trenches are full of water.



Water trenches

Water trenches are great where there is a good source of water and where the soil holds water. Clay soils are best. If there is a continual source of water, it is possible to use them all year, on sloping or flat land.

Water trenches can grow fish and water plants. The land around is then highly fertile for growing vegetables, fruit trees, bamboo and more.

SLOPING-LAND WATER TRENCHES

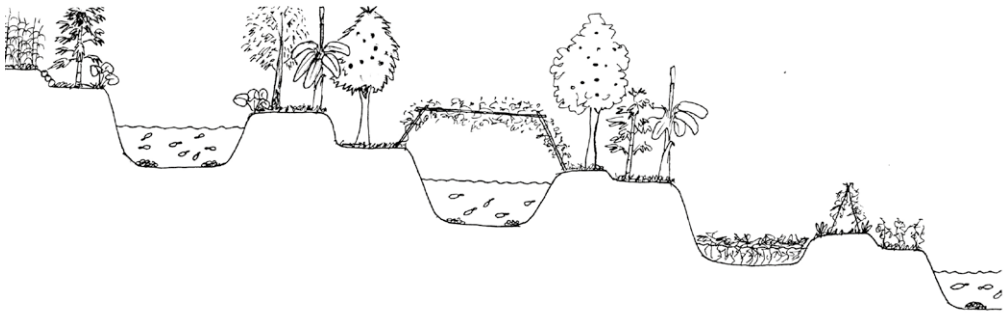
Water trenches can grow fish and water vegetables on land where it is too steep for large fishponds. However, very steep slopes are too hard to dig and manage water trench systems. On sloping land water trenches are similar to swales, so dig them on contour. See Permaculture Design (**Ch 3**) for how to measure contours and make swales.

The water trench size is wider and deeper than for swales. The trenches should be about two to three metres wide and one to two metres deep in the middle. The size depends on the slope of the land (smaller water trenches for steeper slopes), the amount of land and what you want to grow – fish need wider deeper water trenches than water vegetables. Create small shelves for growing plants and vegetables. The trenches are closer together as well, with about three to five metres between each trench.

Water flows from trench to trench by using:

- Pipes made from bamboo, plastic or metal
- Overflow trenches lined with rocks

The soil between each trench stays moist and is ideal for growing vegetables and fruit trees. Build structures for trellising over the trenches to provide some shade and give more production area.



FLAT-LAND WATER TRENCHES

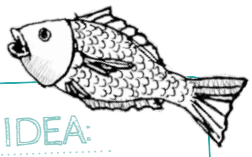
Water trenches are great for flat land too. They can be larger than those for sloping land, but the size can be whatever is best for your land and needs. They are especially good for changing flat land that is continually wet, such as swamps, into highly productive land.

A great flat land example is water running through a series of wide trenches, such as paddies, where people grow water spinach. Between the water trenches the land is very productive. The trenches do not need to be on contour (there is no contour), nor do they need overflow pipes. The trenches can all join up, or there can be an overflow trench.

Be careful: it is important to control the water, the pond edges must be above land level and the pond designs must be able to cope with extreme conditions.

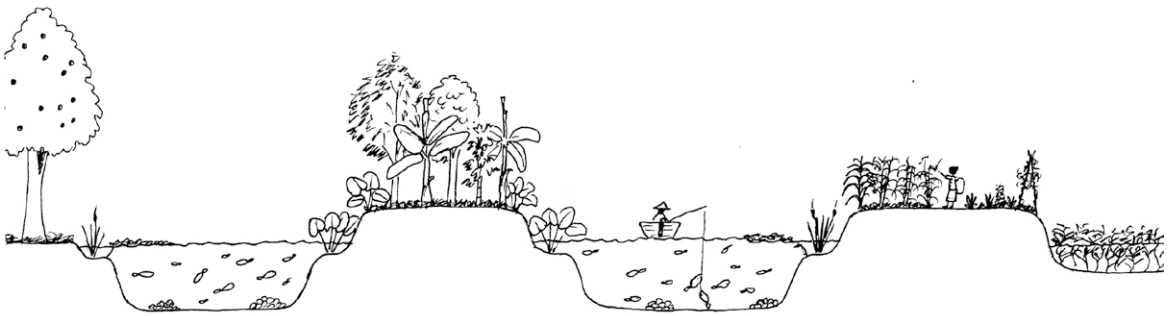
Benefits:

- Water trenches create **lots** of edges which create more production.
- They stop erosion on sloping land.
- When you clean the water trenches the soil, containing a lot of nutrients, is good fertiliser and it can increase the amount of soil between the water trenches.



SMART IDEA:

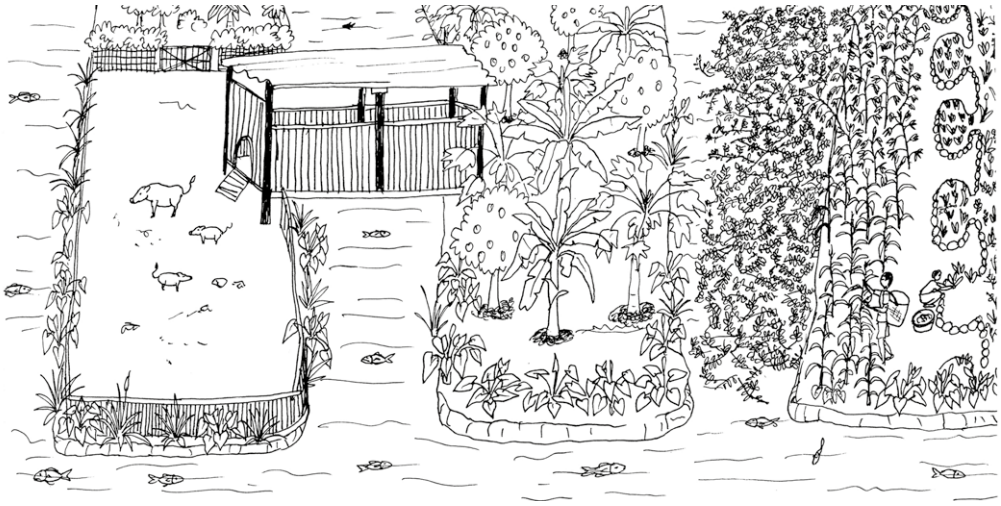
Use water trenches with chickens, pigs, ducks and rice paddies, as well. However, be careful to keep the ducks and fish separate.



Chinampa systems

Chinampa systems originate from the Aztec culture of Mexico. They are a form of water trench and land production system, but instead of digging out water trenches, they actually create land islands in shallow lakes! The technique starts by creating rectangular island walls. Long poles dug into the lake floor form lines, to which woven mats are tied creating walls. The walls are two to three metres apart. More woven mats connect the walls – about 20 cm below the water surface – then on top the added mud and manure create raised garden beds.

Water-loving productive trees planted at the corners and edges secure the islands as their roots bind the soil together. Over time, as the amount of soil and manure increase, islands form. They are very productive systems for growing vegetable and fruit.

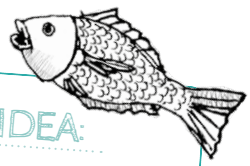


Floating vegetable gardens

The Chinampa-style floating vegetable garden used in Southeast Asia is excellent for areas of high rainfall that flood regularly and large fresh-water bodies.

Build a raft frame using bamboo, as wide as a normal garden bed and as long as you want. Line the sides with reeds then fill the raft with water hyacinth, cut grass, soil from the river or lake bottom and dried manure/compost. The vegetables will send their roots down through the soil and manure, past the water hyacinth and into the water.

They are very successful in fishponds, where the floating vegetable gardens create shade for fishponds and protect fish from birds. These floating rafts become habitats for small birds, fish, frogs and other small water animals, and plants, which helps control pests and improve the environment.



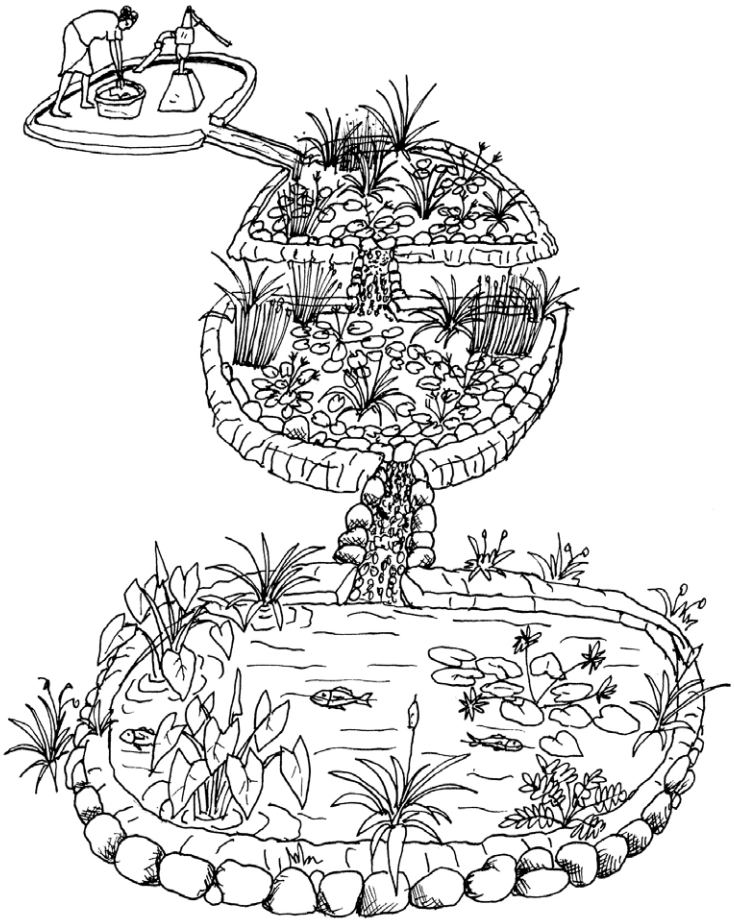
SMART IDEA:

Floating rafts can create natural habitats on lakes and rivers where cattle or humans have damaged the edge of the water body.

Using house wastewater for fishponds

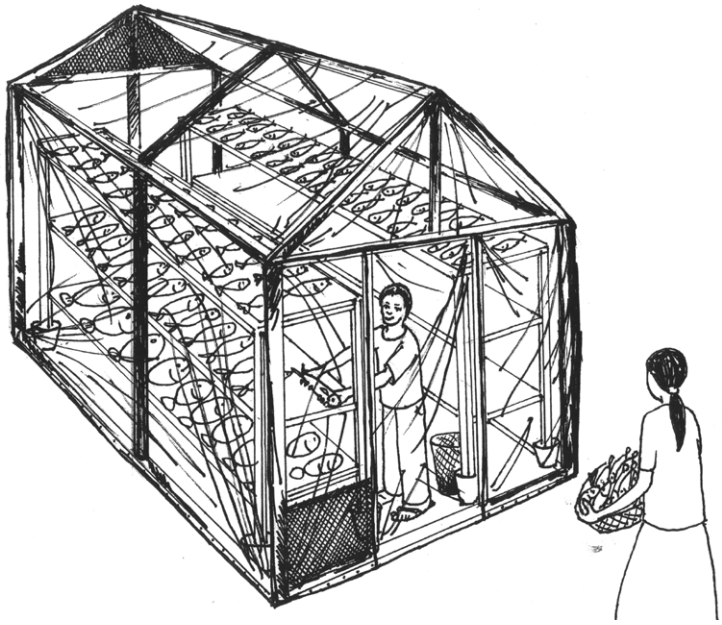
Use the waste (grey) water from kitchens and washrooms for aquaculture, but it is important to remove washing powders in separate ponds before using the water for growing food plants or fish.

Grow water plants in these ponds to clean to water: e.g. phragmitis spp (water reed), water hyacinth, bulrushes, water lilies. Do not use these plants for eating, but instead harvest and use them for mulch around fruit trees. Harvest only 25% at one time because there must be enough plants left to keep cleaning the water. Look in Houses, water and energy (**Ch 7**) for more about house wastewater cleaning.

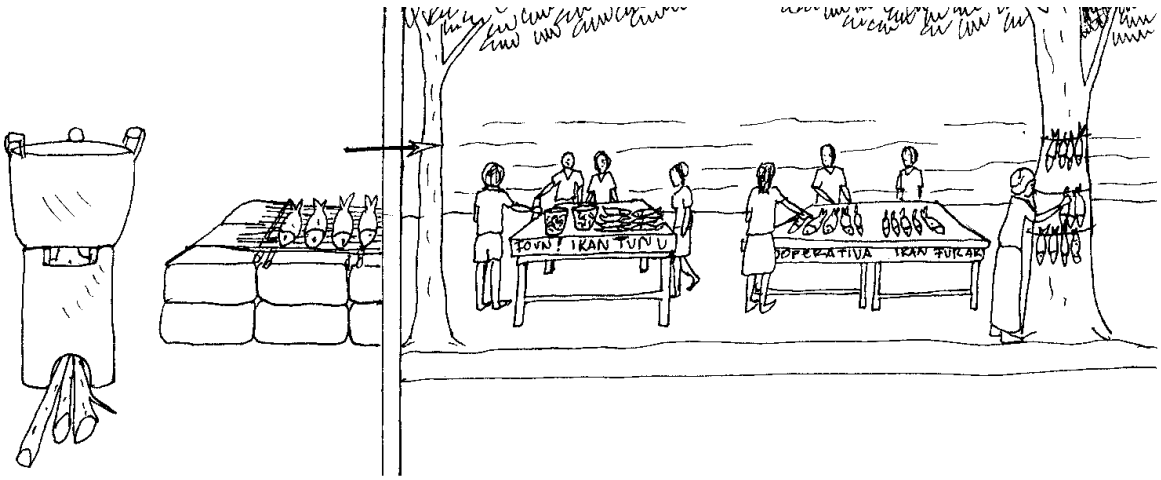


Drying and storing fish

Sometimes you may harvest too many fish to eat or sell. Dry and store the fish so it is not wasted. A solar drier is great for preserving fish because it dries much faster, and insects and animals cannot get close to it. Read Food, health and nutrition (Ch 8) for how to make and use solar driers. Store dried fish in a cool, dry place away from sunlight, and protected from insects and animals. A wire box works well.

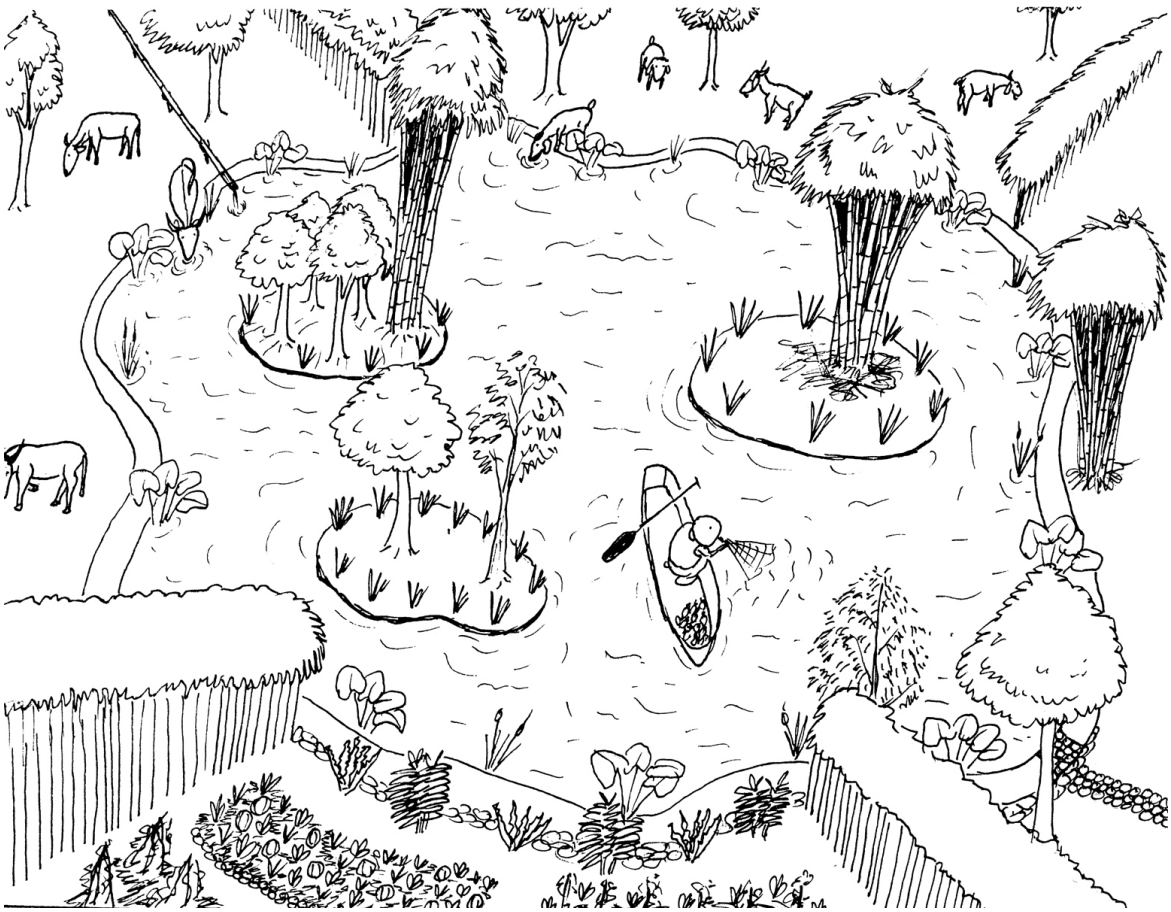


The marketing and selling of fish by small businesses or cooperatives is important for a fish farm's sustainability and growth, especially for selling fish outside the community. Read Cooperatives (**Ch 5**) for ideas.

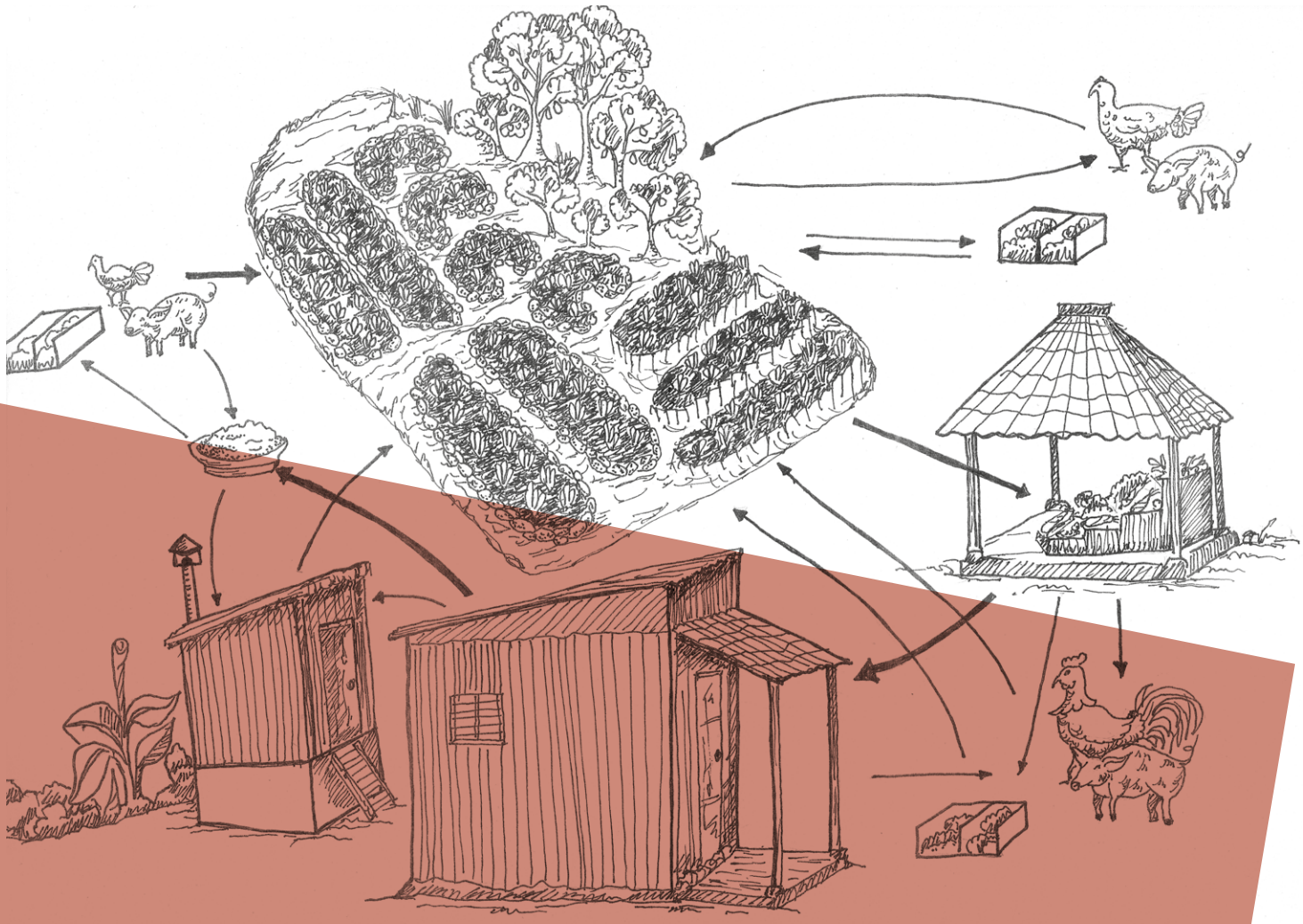


The best aquaculture system you can create is one that suits your own needs.

Every aquaculture system is different because the land is different, the people are different and their needs are different. Choose the strategies and techniques that suit you best and combine them with your own ideas.



AQUACULTURE
CHAPTER NOTES



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References

Websites for permaculture and sustainable communities

We searched a great many websites as we wrote this guidebook. To the website authors and information providers, thank you – you have all contributed to the content of this guidebook!

The growing number of websites providing detailed information and techniques allow better access for everyone and a more equal spread of information. However, sometimes it is hard to find and separate the good websites from those that are not so useful, especially when the internet is slow and/or expensive. Therefore, we have collated some of the best and most useful sites we found and listed them here. We have also included websites that build on the knowledge provided in the guidebook, especially for topics that are too large to explain in detail. Use these sites to research topics, design better permaculture systems and successfully implement your ideas. Bookmark them to make future access easier and share the links.

As the internet grows, it is also becoming more interactive, allowing you to collect and share information, network from local to global perspectives, participate in online workshops and training, generate business and much more.

The following list starts with general websites that provide information and access to large databases on permaculture, sustainability and regenerative practices as well as permaculture groups that you can join. The section after it links websites to the chapters in the guidebook and parts within each chapter to make finding what you need as simple as possible.

Please note: Websites update regularly, may modify their addresses or links, close occasionally and sometimes change permission for use. The following list is only up-to-date at the time of publication. We will update this list regularly and apologise if you have problems, but any changes to the websites are beyond our control.

Contact us if you have any websites to add to this list or notice any problems or changes with websites that are listed here. Thanks!

BEWARE of viruses and scams! There are many viruses that can wipe data from or, at worst, permanently damage your computer, external hard drive or flash drive (USB). Internet cafes have an especially bad reputation for sharing viruses. Only use your external hard drive or flash drive in computers that have up-to-date virus protection, and when your computer is connected to the internet be very careful what you download and which websites you visit.

Search engines

Search engines are incredibly useful, especially when you type in at least four key words to make your search accurate and specific. However, every search on the internet uses energy because of the vast amount of computer processing needed for each search to happen quickly.

There are many different types of search engines now. Some are more sustainable and ethical, such as Ecosia, which donate money from every search to environmental and reforestation projects to offset the search energy used. Another is DuckDuckGo, which does not save or sell your searches to big companies, protecting your privacy. Other search engines are more environmentally aware as they use renewable energy for their computer processing or donate money to charities. Research the search engines available and choose wisely!

General websites

http://permacultureaustralia.org.au
The website for Permaculture Australia and home of Permafund, which supports grassroots permaculture projects across the globe. Contains a lot of excellent news and information too.

www.holmgren.com.au
About the work of Permaculture co-originator David Holmgren, with a lot of useful information and links, especially the 'Permaculture' and 'Ideas and actions' tabs.

https://knowledgebase.permaculture.org.uk
A fantastic store of practical knowledge, links and resources on the Permaculture Association Britain website.

https://permies.com
Where permaculturists around the world present and discuss techniques and strategies on anything to do with permaculture.

https://permaculturenews.org
The Permaculture Research Institute website is a huge store of articles and information on permaculture as well as online forums and the permaculture global network.

http://www.appropedia.org
Amazing and extensive website - a continuously growing source of information on a huge range of topics. Almost every chapter of this guidebook can link to this website for further information. Use their portals then browse portal topics or search for what ever topic you want in the top right search box.

www.journeytoforever.org
An NGO website that covers a huge range of detailed technical information. Topics include community development, organic gardening, alternative technology, seed saving, reforestation and much more. Extensive links to other websites and a great schools project section as well.

www.villagevolunteers.org/resources/sustainable-village-library
A very useful collection of projects, research, curricula, and guides.

http://tropical.theferns.info
Amazing tropical plants database, full of information including cultivation, food uses, medicinal uses and propagation techniques.

www.foodtank.com
General food related website by a think tank pushing for food systems change, with lots of articles and links to related networks and groups.

http://www.infonet-biovision.org
A Kenya based and African focused website but very useful information for all tropical regions. Good for specific information on all organic farming and agriculture, human health, good nutrition and environmental management.

http://answers.practicalaction.org/our-resources
Available in multiple languages with videos or PDFs for download. A huge range of practical information on topics relating to permaculture

https://www.zotero.org/groups/1855053/permaculture_research/items
A permaculture research library that covers many different permaculture and permaculture-related topics.

https://www.wikipedia.org
Wikipedia: a general free reference source in multiple languages - very important and a great example of open source information. A great starting point for any research and detailed information on plant varieties.

https://www.permaculture.org.uk/about/international
Current location for the following international permaculture networks and projects:

- **CoLab - Collaborative Laboratory**: An emerging online network for scaling up permaculture locally to globally
- **PIRN - Permaculture International Research Network:** Connecting researchers, showcasing results, providing a permaculture evidence base
- **IPEN - International Permaculture Education Network:** Practical actions to make permaculture education more effective and cohesive

https://ecovillage.org/
Homepage for the Global Ecovillage Network which 'envisions a world of empowered citizens and communities, designing and implementing pathways to a regenerative future, while building bridges of hope and international solidarity.' This multi-language website links to active groups around the world, and the resources tab leads to news, blogs, a solutions library and more.

http://www.regenerationhub.co
Multi-language website for Regeneration International, connecting the global regeneration movement and providing a platform where you can access projects and groups across the world.

https://www.thebigfix.org/
Collating and sharing positive news and information about solutions to our global problems

Volume 1 Permaculture and people

Ch 1 Permaculture ethics and principles

https://permacultureprinciples.com/resources/free-downloads/
Free downloads of David Holmgren's Essence of Permaculture and colour posters in multiple languages

Ch 2 Natural Patterns

https://vimeo.com/138951606
A fundamentals of patterns lecture given by Bill Mollison. Copyright to Network Productions Inc (**www.networkearth.org**)

https://vimeo.com/139753183
A patterns application lecture given by Bill Mollison. Copyright to Network Productions Inc (**www.networkearth.org**)

https://en.wikipedia.org/wiki/Patterns_in_nature
Provides background knowledge about patterns in nature including how and why they occur.

Ch 3 Permaculture design techniques and strategies

https://www.youtube.com/watch?v=y6j103TDhMg
'What is permaculture?' short video by Rosemary Morrow in English with French subtitles. Good for the basics of permaculture, patterns and design.

http://www.rivendellvillage.org/beginners-guide-to-permaculture.pdf
A PDF download with some good information on design techniques and lots of great illustrations

http://www.suncalc.net
Very useful tool for calculating sun position and movement at any time of year at any location around the world.

Ch 4 Urban and community permaculture

https://transitionnetwork.org
The transition network is an international movement of communities coming together to reimagine and rebuild our world. The website explains the transition idea, process and goals, how to join or create transition groups and has lots of articles, stories, information and blogs.

DISASTER RISK REDUCTION AND PREVENTION

https://lists.riseup.net/www/subscribe/permaculturedrr
A global permaculture group working to support and promote permaculture for disaster risk reduction (DRR), disaster prevention and emergency preparedness. Also a Facebook group: Permaculture and disaster risk reduction.

www.idepfoundation.org
Loads of fantastic resources on disaster risk reduction can be purchased through their media page - **http://www.idepmedia.com/** or contact them at **info@idepfoundation.org**

Cookstoves, ovens and solar cookers – See Ch 8 Food, health and nutrition section

Sustainable house design and construction – See Ch 7 Houses, water and energy section

TREATING CONTAMINATED SOILS WITH FUNGI

http://www.resilience.org/stories/2014-07-07/mycoremediation-bioremediation-with-fungi-growing-mushrooms-to-clean-the-earth-a-mini-review/
A good technical explanation of the process, but hard for people without good English language skills. Contains links to other articles and papers too.

Use search words 'clean contaminated soil with bioremediation fungi' to find many videos, including - **https://www.youtube.com/watch?v=KO1WjFRL_XA** about how mushrooms are helping to clean up oil spills in the Ecuadorian Amazon.

COMMUNITY SUPPORTED AGRICULTURE (CSA)

https://communitysupportedagriculture.org.uk/what-is-csa
An explanation on community supported agriculture with further links at the bottom of the page.

https://en.wikipedia.org/wiki/Community-supported_agriculture
A detailed explanation of the American version of community supported agriculture.

FOOD SOVEREIGNTY

http://www.globaljustice.org.uk/what-food-sovereignty
Good explanation of food sovereignty and some of the groups working with communities and farmers to achieve it. The 'Find out more' section at the bottom of the page is very useful.

www.viacampesina.org
Comprehensive multi-language website of the international peasant movement for food sovereignty. With lots of information, articles, manuals and videos available, the website is easy to use and easy to find local groups and events.

http://www.foodsovereignty.org
Global initiative representing food sovereignty efforts and producing articles and guidelines enabling local groups and communities to be more effective and better equiped.

www.foodfirst.org
The website of Food First who work to end the injustices that cause hunger and help communities to take back control of their food systems through research, education and action.

SOCIOCRACY AND DEEP DEMOCRACY DECISION MAKING AND GOVERNANCE TOOLS

http://www.sociocracy.info/about-sociocracy/what-is-sociocracy
Very detailed website about what sociocracy is and how it can be applied and used.

http://sociocracy30.org
Slightly different version of sociocracy with detailed information and all open-source.

http://www.deepdemocracyinstitute.org
Website for the Deep Democracy Institute that explains about deep democracy and the methods, purpose and programmes involved.

http://deep-democracy.net
Deep democracy training and information.

LOCAL ECONOMIES AND CURRENCIES

https://transitionnetwork.org/about-the-movement/what-is-transition/reconomy
These pages from the Transition Network website provide information and links on creating strong and resilient local economies, including local currencies.

http://www.centerforneweconomics.org/content/local-currencies
Detailed information about local currencies and a large list of links to further resources and organisations.

https://www.community-exchange.org/docs/Community_Currency_Guide.pdf
Excellent PDF about community currencies - what they are, how to set one up and case studies.

http://grassrootseconomics.org/bangla
Local currency initiative in Kenya with great explanatory video.

https://www.community-exchange.org/home
Global community exchange portal where you can connect with groups around the world that operate various types of exchange systems for goods and services.

Ch 5 Cooperatives

www.ica.coop
The International Cooperative Alliance multi-language website is an extensive and detailed website. It is very useful and based on cooperative ideals. A lot of the information is based around larger organisations, not small community cooperatives, but it can be adapted.

Ch 6 Trainers Guide

Rosemary Morrow has an excellent book called 'Earth User's Guide to Teaching Permaculture'. It is very useful for anyone teaching or wanting to teach Permaculture Design Courses and is available from **http://www.bluemountainspermacultureinstitute.com.au** or other online permaculture bookshops.

http://www.bluemountainspermacultureinstitute.com.au/resources/permaculture-teaching-matters
Rosemary Morrow's free-to-download guide for a Training of Trainers course. This is very important for improving the quality and effectiveness of all permaculture training. Just reading this book is very useful! In this guide there is a **reference section (P178)** that provides many links to many other articles, websites and training information.

https://www.learning-styles-online.com/overview
This page outlines seven difference styles of learning and you can click on each style to learn more about them. Here is a good infographic: **http://edudemic.com/wp-content/uploads/2012/11/7-styles-of-learning.jpg**

https://www.permaculture.org.uk/ipen
Current website for the International Permaculture Education Network (IPEN) project. Through practical actions IPEN is looking to increase coherence and effectiveness of permaculture education across the world with a strong focus on tropical countries.

https://www.permaculture.org.uk/ipen/education-resources
A range of downloadable resources for permaculture education.

Volume 2 House and Garden

Ch 7 Houses, Water and Energy

HOUSES AND BUILDING

http://naturalhomes.org
Full of amazing pictures, lots of information and inspiration about natural building, natural energy and much more. A lot of the information is for temperate climates but many ideas can be adapted for tropical climates.

http://www.earthbagstructures.com
Very detailed multi-language website describing many different examples of earth bag building in words, photos and diagrams. There are links at the bottom of the page to other useful natural building websites and blog sites.

https://insteading.com/blog/earthbag-homes/
Great range of examples of earth bag building - photos, videos, explanations and many links to other good websites too.

www.networkearth.org
Use the "Art of Natural Building" section in this website to find a lot of information about natural building with explanations of how to use different building materials. Great information, but unfortunately not many pictures. Has information on other topics as well.

www.oasisdesign.net
Has a lot of good information about all aspects of house design and construction, compost toilets, grey water systems etc. Use the links button to find many other useful websites

http://theconstructor.org/structural-engg/bamboo-reinforced-concrete-mix-design-construction/15054
Detailed information about using bamboo instead of reinforced steel for building foundations

http://inhabitat.com/this-amazing-bangladeshi-air-cooler-is-made-from-plastic-bottles-and-uses-no-electricity
or
http://observers.france24.com/en/20160602-bangladesh-air-conditioner-plastic-bottles-technology
Build a natural air conditioner for cooling a house using simple materials including old plastic drink bottles

http://www.climatechangenews.com/2012/01/10/let-there-be-light-solar-power-bottles-bring-affordable-light-to-the-masses
Article and video on using plastic bottles to make solar sky-lights.

COMPOST TOILETS

http://www.pacificwater.org/userfiles/file/mr0249.pdf
Excellent PDF on compost toilets explaining about different types for different situations, with lots of illustrations and simple clear text.

WASTE

www.theworldcounts.com
Amazing real-time facts about resource use, waste and over-consumption.

https://wasteaid.org.uk/toolkit
Great range of PDF downloads on waste management, reusing waste and creating small businesses from reusing waste products.

https://inhabitat.com/lego-like-building-blocks-of-recycled-plastic-allow-colombians-to-build-their-own-homes
One of many examples about turning plastic waste into building products or furniture.

WATER

http://www.warkawater.org
A website about a project, technologies and products for collecting, storing and providing clean water in difficult places. Click on **http://www.warkawater.org/warka-tower/** for information specifically about the water collection technology.

http://www.fastcodesign.com/1670546/a-simple-solar-oven-makes-salt-water-drinkable
A simple solar oven design for making salt water drinkable on a family scale.

https://en.wikipedia.org/wiki/Portable_water_purification
Good general information about various forms of water purification and how they work.

https://sawyer.com/products/sawyer-mini-filter
A product that can be used for filtration of water to drink, and the website also explains about the process of micron filtration.

WATER PUMPS

http://www.climate-kic.org/case-studies/turning-on-the-tap-with-aqystas-barsha-pump
A water pump that uses water flow energy to pump water for irrigation.

https://answers.practicalaction.org/our-resources/collection/mechanical-power-1
Webpage with PDF downloads about various water pumps.

ENERGY

https://answers.practicalaction.org/our-resources/community/energy-6
A great multi-language resource of guides, projects, case studies and examples about a range of energy topics – biogas, solar, wind, hydro, biofuels, mechanical power and more.

https://energypedia.info/wiki/Main_Page
Comprehensive website that explains in detail about different forms of renewable energy and fuels. It provides case studies from many countries and information on how to build, maintain and secure an appropriate energy supply.

http://www.energyplanet.info
Alternative energy news, and information about renewable energy technologies. Use the index on the right to access a range of websites on specific topics.

http://reneweconomy.com.au
A good website for following the latest developments in renewable energy. It is Australian focused but also has a lot of articles from around the world.

https://www.youtube.com/watch?time_continue=5&v=3AZv6MjZylo
The first part of this video explains a very simple biogas system, after that a more complex system is explained, which could easily be adapted and simplified.

http://thepreppingguide.com/make-your-own-biogas/
Information on how to make a simple biogas system with photos, and a good video at the bottom of the article for a larger biogas system using simple materials. Please note - we are only referring to this page of the website, which is not a recommendation to the entire website.

BICYCLE POWERED TECHNOLOGIES

http://offgridquest.com/energy/pedal-power-how-to-build-a-bike-generato
How to build a bicycle powered generator

http://www.dacres.org/media/articles/energy/Bicycle-powered-food-station.pdf
A PDF about how to build a grain grinder and food processor using bicycle technology

https://simplyresourceful.blogspot.com.au/2017/01/how-to-build-bicycle-powered-grain-mill.html
A blog page with instructions, photos and video on how to make a pedal powered grain grinder.

CH 8 Food, Health and Nutrition

NATURAL NUTRITION

http://foodplantsolutions.org/programs-category/programs
Click on the country you want for simple but detailed and excellent information on nutritious local plants in many tropical countries in downloadable PDF format. Some country information is still in draft format because the project is steadily developing new materials for more countries.

http://aciar.gov.au/files/node/15487/factsheets_web_version_pdf_74613.pdf
PDF factsheets about nutrient dense green vegetables for the tropics with information about growing, harvesting and using the vegetables as well as the nutrient content.

FERMENTED FOODS

http://bonzaiaphrodite.com/2010/07/eat-your-beasties-the-importance-of-cultured-and-fermented-foods
Good website page for information and recipes for fermented food. All in English, and not very easy for non-native English readers, but the recipes are easy to follow and simple. Follow the links at the bottom of the page for specific recipes.

SOLAR DRYERS

http://solarcooking.wikia.com/wiki/Solar_food_drying
A multi-language website containing a lot of information, diagrams, videos and links.

https://energypedia.info/wiki/Solar_Drying
Webpage with great information on solar driers including references, further reading and project examples.

PRESERVING FOOD

http://answers.practicalaction.org/our-resources/community/food-processing-1-2
Very useful information in multiple languages on a range of food processing techniques including preserves, vinegars, dairy and drying foods, oil pressing, bottling techniques, hygiene and much more.

OIL EXTRACTION

http://answers.practicalaction.org/our-resources/collection/nut-processing-and-oil-extraction-1
A huge range of downloadable PDFs in multiple languages that explain and provide technical details for different types of oil extraction.

STOVES AND COOKERS

http://cleancookstoves.org/home/index.html
A website for an organisation promoting clean cooking options across the world. The clean cook catalogue under the technologies and fuels section shows the huge range available, with a variety of fuels including solar.

http://answers.practicalaction.org/our-resources/item/rocket-stoves-options
A small PDF showing a range of rocket stove options.

www.solarcookers.org
An excellent multi-language website about making and using solar cookers of many varieties, as well as other food technology. **http://solarcooking.wikia.com/wiki/Category:Solar_cooker_plans** takes you to plans for building many different cookers.

https://energypedia.info/wiki/Portal:Improved_Cooking
Large and in-depth page with information on stove types, fuels, impacts, monitoring, stove use, creating projects and much more.

Biochar cooking stoves – see Biochar and biochar cook stoves section in Ch 9 Soils.

Ch 9 Soils

COMPOST

http://www.compostguy.com
All about compost, liquid compost and worm farms.

BIOCHAR AND BIOCHAR COOK STOVES

http://biochar.bioenergylists.org
Full of information including downloadable pdfs and lots of small videos to watch about all aspects of biochar. It also has a discussion group and a list for many other useful biochar website links.

http://www.biochar-international.org
Comprehensive website about the international biochar movement, with lots of information under the 'Learn' and 'Resources' tabs

http://www.biochar-international.org/technology/stoves
A good explanation of the various benefits and types of biochar cooking stoves with some illustrations and many links to more information

http://www.soil-carbon-regeneration.co.uk/biochar
Good information on biochar including detailed instructions on how to make various biochar stoves. It has photos and diagrams as well.

http://servalsgroup.blogspot.co.uk/2009/05/tlud-gasifier-stoves-wood-stove-with.html
A social enterprise company website for their biochar cookstove including a short video on how to use it.

BIODYNAMICS

https://www.biodynamics.com
Official Biodynamics Association website. Good basic information and blogs, contact them about local farms, networks, courses, newsletters and more.

http://www.biodynamics.in
Indian Biodynamic website, with good basic information about biodynamics and a contact point for finding Indian biodynamic farms and courses.

BACTERIAL ACTIVATORS

http://www.compostjunkie.com
Has detailed info on bacterial activators and all things compost. Its also a shop but all the ingredients can be substituted with locally available suitable materials. You can sign up for free booklets as well.

CONTAINER WORM FARMS

http://working-worms.com/how-to-make-your-own-worm-farm
Easy to use, detailed information about making and maintaining worm farms including illustrations, short videos and pdfs to download. The techniques they use can be adapted to build worm farms with other materials as well.

http://www.countryfarm-lifestyles.com/Worm-Farming.html
Detailed information on building and maintaining worm farms but not many illustrations or photos.

http://journeytoforever.org/compost_worm.html
Really good general information which can be easily adapted for other materials.

http://www.redwormcomposting.com
A huge amount of information can be found by following the tabs on the left - for people who want to learn a lot!

Ch 10 Family Gardens

Biodynamics – see websites in Ch 9 Soils

AFRICAN KEYHOLE BEDS

https://www.sendacow.org

https://www.youtube.com/watch?v=ykCXfjzfaco
This is their short video on making an African keyhole bed.

WICKING BEDS

http://gawlerenvironmentcentre.org.au/wp-content/uploads/2016/07/Handout-2016-Wicking-Bed-Info.pdf
http://gawlerenvironmentcentre.org.au/wp-content/uploads/2016/07/Handout-2016-How-To-wicking-Foam-box.pdf
http://gawlerenvironmentcentre.org.au/wp-content/uploads/2016/07/Handout-2016-How-To-wicking-Raised-bed.pdf
Easy-to-follow PDFs about wicking beds, making them in foam boxes and making raised garden wicking beds.

HUGELKULTUR

http://www.inspirationgreen.com/hugelkultur.html
Good simple explanation of hugelkultur with great illustrations, photos, examples and links.

CH 11 Seed saving and propagation

www.seedsavers.net
The Seed Savers Network are based in Australia and have provided workshops and helped start a numerous seed saving groups in Australia and many other countries. Their website provides a lot of information, photos and blogs, as well as books and films to purchase.

GRAFTING

http://www.extension.umn.edu/garden/yard-garden/fruit/grafting-and-budding-fruit-trees
A good website that explains all the basic aspects of grafting in words and pictures. Easy to find what you want.

http://www.wikihow.com/Graft-a-Tree
Very detailed step-by-step guide for many different types of grafting, with excellent illustrations.

SEED VIABILITY TESTING

http://www.theprairiehomestead.com/2015/03/how-to-test-seeds-for-viability.html
A simple easy to follow guide for testing your seed viability rate.

Volume 3 Regenerative Agriculture

Ch 13 Sustainable Agriculture

Biodynamics – See Ch 9 Soils references

www.vetiver.org
A comprehensive website all about vetiver grass! Each section comes as an online or downloadable pdf and they all have lots of photos and very useful, simple explanations.

ALLEY CROPPING (A TYPE OF AGRO-FORESTRY)

http://www.ingafoundation.org
A great website that explains about alley cropping using the Inga tree. Some good short videos, lots of photos and information in Spanish as well.

http://rainforestsaver.org
Another great websites that explains about alley cropping using the Inga tree. Detailed information including a step-by-step guide and a great animated short video explanation

WATER CATCHMENTS

https://en.wikipedia.org/wiki/Keyline_design
A starting point for understanding good land design for water catchments using the keyline design system, with has links to further information and related topics.

SYSTEM OF RICE INTENSIFICATION (SRI)

http://sri.cals.cornell.edu
A multi-language website that contains a huge base of information on SRI for rice and other crops, including field studies, manuals, photos, videos and much more.

http://ciifad.cals.cornell.edu/sites/ciifad.cals.cornell.edu/files/shared/documents/Styger.pdf
An extensive PDF about SRI for rice and wheat that is practical, easy to read and mostly explained through photos.

https://www.oxfamamerica.org/publications/more-rice-for-people-more-water-for-the-planet
A download PDF publication about SRI showing case studies and results from Mail, India and Vietnam

MUSHROOMS

http://www.wikihow.com/Grow-Organic-Mushrooms
Simple step-by-step instructions and illustrations for growing fungi on logs and with coffee grounds.

http://journeytoforever.org/farm_library/AD40.pdf
Detailed PDF for download about the basic techniques for mushroom production

Ch 14 Integrated Pest Management (IPM)

http://www.oisat.org
Excellent online information service for non-chemical pest management in the tropics. Access the information via tabs for principles, crops, pests or control methods. It also has an extensive library and links.

http://www.infonet-biovision.org/plant_pests
A Kenya based and African focused website but has detailed pest descriptions and organic control methods that are very useful for all tropical regions.

https://www.hortzone.com/blog/2016/10/16/proven-insect-repelling-plants
Good article describing many different insect repelling plants, which also provide many other products and benefits. Other articles on this website have some good information but sometimes aren't very holistic and are occasionally linked to conventional methods or products.

https://www.softfootalliance.com/uploads/8/5/0/7/85075002/the_mobile-boma.pdf
Great PDF explaining a traditional method for protecting livestock from large wild predators

NEEM

www.neemfoundation.org
Excellent website for detailed information about neem trees, neem products and how neem works.

http://www.youthinfarming.org/2011/10/produce-neem-oil-at-home-and-earn-extra.html
Good description about extracting neem oil for household use

Ch 15 Trees

ALLEY CROPPING (A TYPE OF AGRO-FORESTRY)

http://www.ingafoundation.org
A great website that explains about alley cropping using the Inga tree. Some good short videos, lots of photos and information in Spanish as well.

http://rainforestsaver.org
Another great websites that explains about alley cropping using the Inga tree. Detailed information including step-by-step guide and a great animated short video explanation.

GRAFTING

http://www.extension.umn.edu/garden/yard-garden/fruit/grafting-and-budding-fruit-trees
A good website that explains all the basic aspects of grafting in words and pictures. Easy to find what you want.

http://www.wikihow.com/Graft-a-Tree
Very detailed step-by-step guide for many different types of grafting with excellent illustrations.

MORINGA

http://www.treesforlife.org/our-work/our-initiatives/moringa
An excellent website explaining all about Moringa's many uses and benefits. The site has a lot of other useful information too.

www.moringanews.org
A very good general website for moringa information in French and English. Also excellent for networking and the links to other groups and websites.

VETIVER GRASS

www.vetiver.org
A comprehensive website all about vetiver grass! Each section comes as an online or downloadable pdf and they all have lots of photos and very useful, simple explanations.

Ch 16 Bamboo

www.inbar.int
The International Network for Bamboo and Rattan (INBAR) website has a lot of information. It explains how bamboo can help in achieving many sustainable development goals (SDGs), offers links to a range of projects and through their resource tab offers a wide range of information about growing, harvesting and using bamboo through books, downloadable PDFs and articles.

http://www.bamboocentral.org/index1.htm
Instructions for treating bamboo with boron can be downloaded from the Environmental Bamboo Foundation - click on the treatment manual tab to access the PDF

http://www.completebamboo.com
Aimed at a USA audience, but contains a lot of good basic information on growing and maintaining bamboo for all countries.

http://www.guaduabamboo.com
A large amount of information and articles under the bamboo tab as well as free PDF downloads on lots of topics including bamboo building and bamboo furniture. (**https://www.guaduabamboo.com/bamboo-pdfs**)

http://humanitarianlibrary.org/sites/default/files/2014/02/INBAR_technical_report_no20.pdf
A large and comprehensive PDF on bamboo and using bamboo for construction

http://theconstructor.org/structural-engg/bamboo-reinforced-concrete-mix-design-construction/15054
Information for using bamboo instead of reinforced steel for building foundations. This website has other good articles on bamboo as well.

Bamboo The Gift of the Gods 2003 Oscar Hidalgo – Lopez ISBN 958-33-4298-X
This is an important book if you want to build with bamboo, especially for large buildings and for creating a livelihood from bamboo building. South American architects and engineers have been developing this technology for many years.

Ch 17 Animals

ANIMAL FEED

http://www.tropicalforages.info
A detailed website with a huge database of forage plants for animals. Use the selection tool to insert your details then access appropriate forage plants, or use the forages fact sheets to find out about any plant.

http://www.feedipedia.org
Multi-language website that provide valuable information on all types of animal feed, especially forage plants. Use the feed category tabs on the left side

CHICKEN HEALTH

http://www.worldpoultry.net/Breeders/General/2009/7/Herbal-trees-used-as-antibiotics-for-broilers-WP006936W/
An article on using plants as natural antibiotics and the results for the different plants

http://www.countryfarm-lifestyles.com/aloe-vera-for-chickens.html#.WAYlvdw7SVs
An article on using aloe vera for general chicken health and treating some sicknesses.

GOAT MANAGEMENT

http://publications.cta.int/media/publications/downloads/371_PDF.pdf
A comprehensive PDF on managing goats in the tropics. Good basic information although some of medical treatments rely too much on curative chemical treatments rather than preventative and/or natural treatments.

www.fiascofarm.com
This website contains a lot of information about goat farming, milking goats and making products from goat milk. The methods described are all natural and mostly simple. Some products described are not available here, but it still provides many useful techniques and a lot of good information.

COWS AND BUFFALOS

http://pdf.usaid.gov/pdf_docs/PNADQ897.pdf
A PDF on making silage for high quality livestock feed

https://www.softfootalliance.com/uploads/8/5/0/7/85075002/the_mobile-boma.pdf
Great PDF explaining a traditional method for protecting livestock from large wild predators

BEEKEEPING

http://answers.practicalaction.org/our-resources/collection/beekeeping-6
A range of PDFs on beekeeping in multiple languages

http://www.beesfordevelopment.org/resource-centre
The Bees for Development resource centre is divided into different sections to make finding what you need much easier, with an extensive library, teaching resources, movies, journals and more.

http://www.buzzaboutbees.net/support-files/how_to_build_a_tbh.pdf
A PDF to download on making a top bar bee hive. It has lots of photos, and is easy to follow.

http://www.planbee.org.uk/uploads/Bees_for_Development_Beekeeping_with_top-bar_hives_March_2006.pdf
Good basic management information for top bar hives in a small PDF

http://publications.cta.int/media/publications/downloads/1290_PDF.pdf
A PDF about bee products - the range of products and how to collect, make, market and sell them.

Ch 18 Aquaculture

www.enaca.org
Network of Aquaculture Centres in Asia-Pacific website. The information - articles, audio and video - is more for larger scale fish ponds and some information is based on high-external inputs or chemical treatments but it also has a lot of information that is relevant and useful.

http://www.aquaculturewithoutfrontiers.org
A range of information and presentations along with education resources in the form of blogs, articles, videos and slideshows as well as many links to other organisations and networks.

https://steemit.com/permaculture/@reville/aquaculture
From West Timor, in English language but with an Indonesian perspective. Lots of good basic information and photos, with integration techniques for other food production systems too.

Books

Books and other educational materials are vital for ongoing development. Websites are great but books can be used anywhere and provide practical references for successful projects and for reducing mistakes. Good books become treasures, to be shared and valued well beyond their worth.

We encourage local groups, organisations and cooperatives to develop a library of education resources for themselves and for the wider community to use as well. This includes:

- Books large and small
- Reference guides
- Comic style educational readers
- Children's books
- Posters and information sheets
- Flip-charts

Part of community resilience is to have education tools to develop, overcome problems and be self-sustaining.

BOOKS REFERENCED FOR THIS GUIDEBOOK

We are deeply thankful for all the information referenced and learned during the researching for this guidebook. Thank you, the writers and illustrators, for all your efforts in providing these books and reference materials. You have all contributed greatly to expanding the knowledge and resource base for tropical permaculture worldwide.

Earth User's Guide to Permaculture
Rosemary Morrow
Kangaroo Press, 1993

Earth User's Guide to Permaculture – Teachers Notes
Rosemary Morrow
Kangaroo Press, 1997

Bamboo Rediscovered
Victor Cusack
Earth Garden Books, 1997

The Seed Savers Handbook
Michel and Jude Fanton
The Seed Saver's Network, 1993

Permaculture, A Designers Manual
Bill Mollison
Tagari Publications, 1988

Introduction to Permaculture
Bill Mollison
Tagari Publications, 1991

Permaculture – Principles and pathways beyond sustainability
David Holmgren
Holmgren Design Services, 2002

Liklik Buk
Edited by Amanda Twohig
Published by Liklik Buk Information Centre,
Lae, Papua New Guinea, 1986

Sapa, The natural way of growing food in the Solomon Islands
Joini Tutua with Toni Jansen
APACE, 1994

Community Seed Saving – A South Pacific Trainers Manual
Emma Stone
Kastom Gaden Association, 2002

Energy From Nature, 11th Edition
Compiled by Peter Pedals
Rainbow Power Company, 2001

Mud Brick Techniques
Ron Edwards
The Ram Skull Press, 1990

Farming in Ponds and Dams
Nick Romanowski
Lothian, 1994

Fish for Farm Dams
Malcolm R McKinnon
Queensland Department of Primary Industries, 1989

Natural Pest and Disease Control
Henry Elwell and Anita Maas
The Natural Farming Network, Harare Zimbabwe, 1995

Minanao Baptist Rural Life Centre Series (SALT)
Minanao, Phillipines

Notes from Permaculture Design Course and Permaculture for Third World and Indigenous Peoples Course
Robyn Francis
Djanbung Gardens Permaculture Education Centre

Manual for the promotion of Family-Scale Aquaculture in the Northwest Provinces of Cambodia
Prepared by Wayne Gum for UNOPS/CARERE

Organic Gardening
Peter Bennett
Child & Associates Publishing Pty Ltd, 1979

Companion Gardening in Australia
Judith Collins
Lothian

REFERENCES
NOTES

GLOSSARY

A

Aerate	To provide air or enable air to circulate – e.g. aerate the soil.
Agroecology	The study of ecological processes applied to agricultural production systems; the application of ecology to agriculture, as in the conservation of soil and water resources, minimising pollution, and the use of natural fertilisers and pesticides. An ecological approach to agriculture is one that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices.
Alignment	Organisation in a straight line, or a line/s made as such – e.g. contour lines.
Animal tractor	A small to medium sized cage with an open bottom or a fenced area usually for chickens, pigs or ducks but can be for other commonly raised animals too. The animals turn the soil, removing weeds and seeds, and fertilise it with manure. After a period of time – e.g. when the animals have cleaned or turned the ground – the tractor or fenced area is moved to a new position. This method is used after harvest and before planting the next crop.
Annual	A plant that completes its life cycle in one year.
Aquaculture	Aquaculture or aquafarming is any type of water, pond or wetland environment which grows or farms aquatic animals (e.g. fish, eels, crayfish, prawns, etc.) and plants.

B

Biochar (activated charcoal)	Biochar is a stable form of charcoal produced by heating natural organic materials in a high temperature (300 °C to 700 °C), low oxygen process known as pyrolysis. The charcoal is then made active with beneficial micro-organisms, fungi and nutrients.
Biomass	Organic matter – especially plant matter – that can be converted compost, mulch, animal fodder, fuel and soil improver.
Bulb	A bud, usually underground and circular, from which leaves, stems and flowers grow at the top, and roots from the bottom.

C

Canopy	The covering or highest layer of a forest or of an area of plants and trees provided by the tree tops, similar to the roof of a house.
Citrus	A general name for a group of trees of the same family that produce sharp tasting, often large fruit – e.g. orange, lemon, lime, mandarin, grapefruit, pomelo.
Compost	Natural high-quality fertiliser and soil improver that is made from decomposing manure, plant materials and other natural ingredients. "To compost" is to turn plant materials, manure and other natural ingredients into fertiliser.

Compost bay	A structure built and used to make and contain compost.
Condensation	The process of changing from a gas or vapour to a liquid or solid form – e.g. the water droplets that appear on cold surfaces as a result of hot air or steam cooling.
Contour line	A line connecting points of equal height, at the same level from end to end, across a slope.
Cooperative	A farm or enterprise that is communally owned and managed for the economic benefit of its members.
Cross pollination	The transfer of pollen from the male part of the flower of one plant to the female part of the flower of another plant.
Cutting	A piece of a branch from a plant that when planted grows into a new plant.

D

Deficient	Not enough; of a quantity not able to fulfill a need or requirement – e.g. nutrient deficient soil means the soil does not have enough nutrients or not all the nutrients that a plant needs.
Design	To conceive, invent, plan, devise, formulate; Permaculture design applies permaculture ethics, principles and methods to create an outcome that reflects permaculture in action no matter the location, need situation or size. The sequence of activities to complete a design is called a design process.
Diversity	Many different and mixed varieties of animals and/or plants in one area. – e.g. a healthy natural forest has a diversity of plants, animals and birds.

E

Element	One of the fundamental components making up the whole. The elements of something are the different parts it contains.
Energy	The capacity of an organism or physical system to do work. Physical systems can be people, animals, machines, etc. Energy can be created, stored and used.
Evaporation	To change from a liquid or solid shape into a vapour or gas – e.g. water when it boils or water when it dries on the road after rain.

F

Feature (on map)	An important or unique part of the land that is mapped – e.g. house, river, fence.
Fermentation	A chemical process caused by yeasts, bacteria and moulds where organic food is converted into simpler compounds, and chemical energy is produced. It is used for preserving, and making food and drinks – e.g. tempeh, yoghurt.
Fingerling	A young fish usually under a year old, about the size of an adult finger.

Fry (in aquaculture)	Young, baby fish.
Function	The intended use or purpose of a person or thing – e.g. some functions of bamboo are to stop erosion, make a living fence, reduce wind, provide poles, provide food, etc.
G	
Garden bed	An area for growing small plants. Permaculture garden beds suit the land and climate, and are designed for protecting and building soil. They are usually raised, with paths on the outside and sometimes have borders.
Germination	The process of a seed coming to life and growing.
H	
Hedge	A thick row of bushes or small trees.
Holistic	Looking at the whole of something or someone and not just its parts. Permaculture uses this approach to observe and include all separate parts into a single integrated design.
I	
Input	Something that is a resource needed for a system to function properly. In a permaculture system an input is carefully chosen; preferably it is local, sustainable, renewable and waste or output from a different system.
Integrate	Bringing together two or more individual parts or systems so they become connected and inter-related, creating a new whole system.
Integrated Pest Management (IPM)	Combines different natural techniques for pest management to reduce the chances of pest problems, the size of the pest population if problems occur and natural control techniques if necessary.
L	
Larva	An insect after it has hatched from an egg and before it changes into its adult form. More than one larva is larvae.
Leach	To lose soluble elements from a substance by a liquid passing through it – e.g. when soil loses nutrients as a result of wet season rain.
Living fence	A fence built by growing living plants close together in a row. If legume trees are planted they which can be pruned regularly to produce animal food, compost material, mulch and nitrogen in the soil.

M

Microclimate	The summation of environmental conditions at a particular site as affected by local factors rather than regional ones.
Micronutrient	A mineral or vitamin required in very small amounts by plants and animals for health and growth.
Mineral	A naturally occurring solid inorganic substance with a characteristic chemical composition and structure.
Mulch	Organic material spread on the ground and covering the soil, usually around plants, to inhibit weed growth, prevent excessive evaporation or erosion, enrich the soil and moderate soil temperatures, etc. (Mulch can be inorganic, such as plastic, but it is not recommended or sustainable.)

N

Nematode	The general name for a class of very small worms which live in most environments including the soil. Most types of soil nematodes are beneficial but some types are parasitic and cause damage to plant roots by eating them.
Nursery	A protected area where plants are grown from seeds, seedlings or by propagation in order to transplant into other areas or to sell when they have reached the appropriate healthy size.
Nutrient	A substance that provides the food necessary for life and growth.

O

Organic matter (OM)	Material in or on top of the soil which is of plant or animal origin.
Output	Materials, products or yields that are created. In permaculture all outputs, even waste, are used and reused as inputs in other parts of a house, community or production system.

P

Pathogen	Any virus, bacterium or other micro-organism that can produce disease.
Perennial	A plant that continues its growth for three or more years.
Pest predator	A bird, animal, insect or spider that eats the pests which damage crops.
Photosynthesis	The chemical process by which a plant uses sunlight and chlorophyll to make sugars from water and carbon dioxide absorbed from the air.
Pioneer	A plant that is usually the first to start growing in a new area of land, which has possibly been damaged by fire or has no other vegetation – e.g. pioneer plant.

Pollination	When a powder produced by the male part of a flower is carried by insects or the wind and causes the female part of the same type of flower to produce seeds.
Prevailing wind	The usual direction the wind comes from.
Propagation	To take a section of a plant from which to grow more plants.
Prune	To cut off some parts of a tree or bush so that it grows better, removes dead or diseased branches or improves the shape.

R

Regenerate	To re-create, renew, reconstitute, or restore, especially in a better form or condition. In permaculture this can refer to trees, soil, rivers, an ecosystem and even a community. Regeneration promotes health, diversity and resilience.
Resilient	Capable of recovering easily and quickly from misfortune or illness and less prone to suffering during times of stress or hardship – e.g. Improved water catchment and storage will increase plant survival rates during drought conditions.

S

Scale (on map)	The ratio between the size of something real and that of a representation of it.
Seed saving	The act of preserving, using and increasing a seed supply from quality plant sources, by careful growing, selecting, cleaning, drying and storing the seeds each season.
Soil biota	The mainly microscopic plant and animal life in the soil.
Soil improver	A material that enhances the quality of soil, increasing biological and healthy fungal activity and/or the amount of humus or organic matter.
Succession	The gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another over time until a stable climax is established.
Sustainable	Something that lasts and can go on indefinitely, based on available resources. It is midway between degenerative and regenerative.
Swale	A swale is a trench dug in a line along the contour of a piece of land with a mound of soil, rocks or other materials made in a line directly below it. It is built to collect, spread and store water in the ground, and also to catch soil and organic matter. Sometimes on difficult land it is only possible to make the mound.
System	The manner in which parts of something fit or function together; a network or set of methods for doing something – e.g. a permaculture design brings separate strategies and techniques together into one system.

T

Tree (or living) terrace	A system of raised flat banks of soil, usually on a hillside, for planting crops where the bank is formed and stabilised by a row of closely planted trees or plants, carefully chosen to be productive, good at protecting the soil from erosion , non-competitive and easily managed.

V

Value-added	When a product or material is changed, improved or processed in order to create a new product or material and increase its price or worth – e.g. making jam or marmalade from fruit; making furniture from bamboo poles; making compost from manure, leaves and kitchen waste.
Ventilation	When fresh air is allowed to enter an enclosed space.

W

Wholefood	Food that is not packaged or changed from its original form. It can be fresh, dried or naturally preserved.

Y

Yield	The results of human work and/or a natural process – e.g. In a permaculture system there are many results or yields by using all of the different functions of each element.

Partners

Sponsors

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Dedication

Rob Swain, 1955–2017, lived his life as he worked with us on this guidebook: with endless generosity, humble wisdom, joyful enthusiasm, careful dedication, a profound respect for our earth and much grace and laughter. We will continue your legacy, grow from your knowledge and remember you with love. Journey well.

Sustainable Development Goals (SDGs)

The Tropical Permaculture Guidebook enables these 12 UN Sustainable Development Goals to be advanced and achieved.

CarbonSocial

We are working towards carbon neutrality by offsetting through CarbonSocial – the first ethical, social and environmental carbon credits from Timor-Leste.

CarbonSocial credits are produced under the WithOneSeed community forestry program and are the only internationally certified Gold Standard credits available from Timor-Leste. Importantly, funds raised from the sale of CarbonSocial credits are used to directly pay small landholder subsistence farmers to plant and manage the forests where they live, through the WithOneSeed program.